BRITISH AEROSPACE

E·A·P

EXPERIMENTAL AIRCRAFT PROGRAMME

AN AEROGUIDE SPECIAL BY BILL GUNSTON

FOREWORD BY DAVID EAGLES

EAP
Bill Gunston

Published by Linewrights Ltd, 118 High Street, Chipping Ongar, Essex CM5 9EB, England

ISBN 0 946958 22 X

Designed and produced by Roger Chesneau
Colour profile and line drawings by Mike Keep

Typesetting by Typesetters (Birmingham) Ltd, Smethwick, West Midlands.
Colour and monochrome reproduction by Anglia Reproductions, Witham, Essex
Printing and binding by Heffers Printers Ltd, Cambridge

Printed in Great Britain

This book would not have been possible without the wholehearted co-operation of British Aerospace, Warton, and the publishers would like to thank in particular John Vincent, Executive Director EAP/EFA; David Greenhalgh, Assistant Project Manager EAP; Bill Scarfe, Head, Avionics Laboratory; and Geoffrey Hill and his staff, whose unstinting and patient assistance was of epic proportions. Special mention must be made of Dave Eagles, Executive Director Flight Operations and EAP Chief Test Pilot, for generously contributing the Foreword. For help with photographs and technical information, thanks are due to Martin Brodie and David Howie, Rolls-Royce; Mike Ottewell, John Fowler & Partners/Ferranti Defence Systems; L F E Coombs, Smiths Industries Aerospace & Defence Systems; Peter Simmons, GEC Avionics; Del Holyland, Martin-Baker Aircraft Co; Simon Raynes, BAe Air Weapons Division; Chris Wall, Lucas Aerospace; and Derek N James, Dowty Group. Unless otherwise stated, photographs included in this book are the copyright of British Aerospace.

Front cover: Theory into practice: first flight, 8 August 1986.

Linewrights LTD

Price £3.95 net UK only

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FOREWORD

The EAP has been a very important step for British Aerospace, bringing together all the important new technologies and successfully integrating them into an easy-to-manage, high-performance demonstrator. It was an exciting privilege to make the first flight on the afternoon of 8 August 1986 and to be the first to sample this unstable layout.

The aircraft was very quick off the runway. We had already sampled take-off acceleration during several fast taxi runs during the week preceding flight, but it was a great thrill to leave the power on now and rotate it into flight. The immediate impression, and one described by each pilot who has flown it since, was that EAP felt immediately very steady, very attitude-stable, and yet responded instantly to control inputs. In short, a delightful aircraft to fly.

The more artificial the stability in an aircraft the easier it is to simulate. We had flown many hours of EAP simulation prior to flight and had found the handling straightforward and pleasant. First flight showed the simulation to have been very accurate in almost every area, and where there were differences, the aircraft was always better!

We had planned a full hour's testing for flight one and the whole schedule went like clockwork with an initial look at the handling with landing gear up and down, an acceleration to Mach 1.1 at 30,000ft, and some enjoyable discoveries of delightful behaviour in the landing circuit. The delta wing, combined with a very soft undercarriage, made for a very soft landing – a perfect return from my most memorable flight.

Surprisingly there were no defects from the first flight which would have prevented us flying again immediately. As it was, the aircraft made nine flights within its first week of operations – surely an indication of the soundness of design and construction of this unique aircraft which will show us the way towards our next generation of fighters.

David Eagles
Executive Director, Flight Operations
British Aerospace, Warton

Its tail braking 'chute just starting to stream, EAP concludes a successful maiden flight, 8 August 1986 (below). The aircraft was aloft for 67 minutes (right), carrying out general handling manoeuvres, including Dutch rolls. Commented Dave Eagles (below right) afterwards: 'It's superb – remarkably agile and yet very easy to fly. I think it is ideal and what every fighter pilot would want. I wish we were making eight hundred rather than one!' For its first outing, EAP had 'Fly Navy' zaps added just behind the cockpit.

A FIGHTER FOR EUROPE

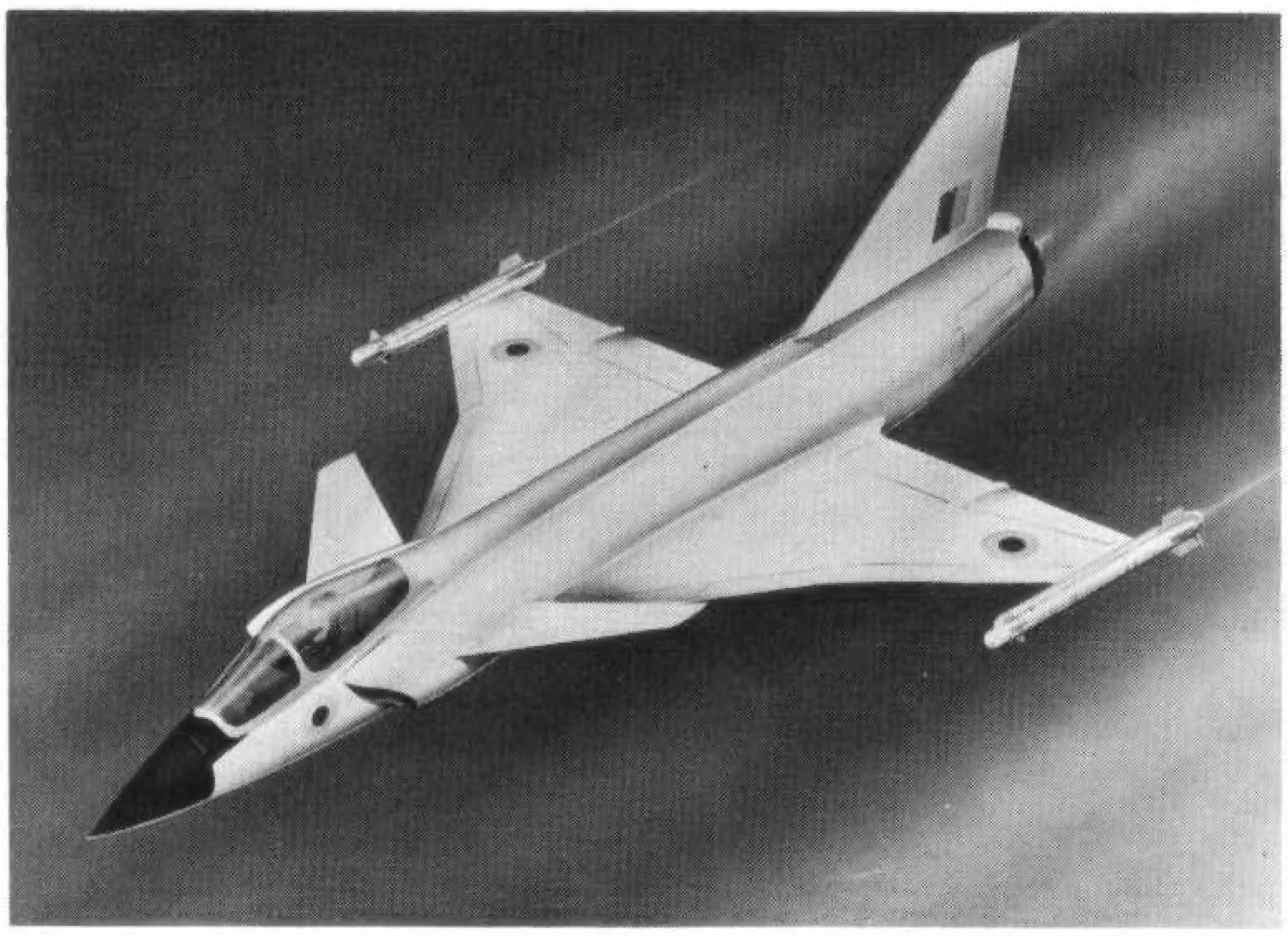
Thirty years ago the British government decreed that there were to be no more manned combat aircraft, of any kind. The effects of that gigantic blunder are still being felt. One of them is that since the Lightning – which in April 1957 was described as having 'unfortunately been developed too far to cancel' – the British aircraft industry has never been able to produce a fighter. Instead it has concentrated on building three of the world's best tactical attack aircraft, two of them in collaboration with foreign partners. One of the latter, the Tornado, has a variant which is a long-range stand-off-kill interceptor, and the third type is a unique, single-engined, short take-off and vertical landing (STOVL) aircraft – the Harrier – which in the author's view opens the way to the only kind of air power that might survive more than a few minutes in any future war. This STOVL machine was created by British Aerospace's Kingston team, which has ever since been frustrated in its efforts to move on to the obvious next generation. The reason it has been frustrated is that the official view, apparently shared by all the generals and air marshals, is that in any major war the enemy would not be so unsporting as to use his missiles to wipe all NATO air bases off the map in the opening seconds. Instead the bases would suffer no more than slight inconvenience from a few craters, so conventional air power will be perfectly able to operate. There has thus for at least ten years been a clear need among the European NATO nations for an advanced modern fighter. The Experimental Aircraft Programme, the subject of this book, is the first tangible expression of this need. It is not a fighter but a single demonstrator aircraft, with not even the parts of a second one in existence. Having made these telling and perhaps controversial points, the author feels a lot better and can get on with presenting to the reader what is unquestionably the most exciting new aeroplane in the world.

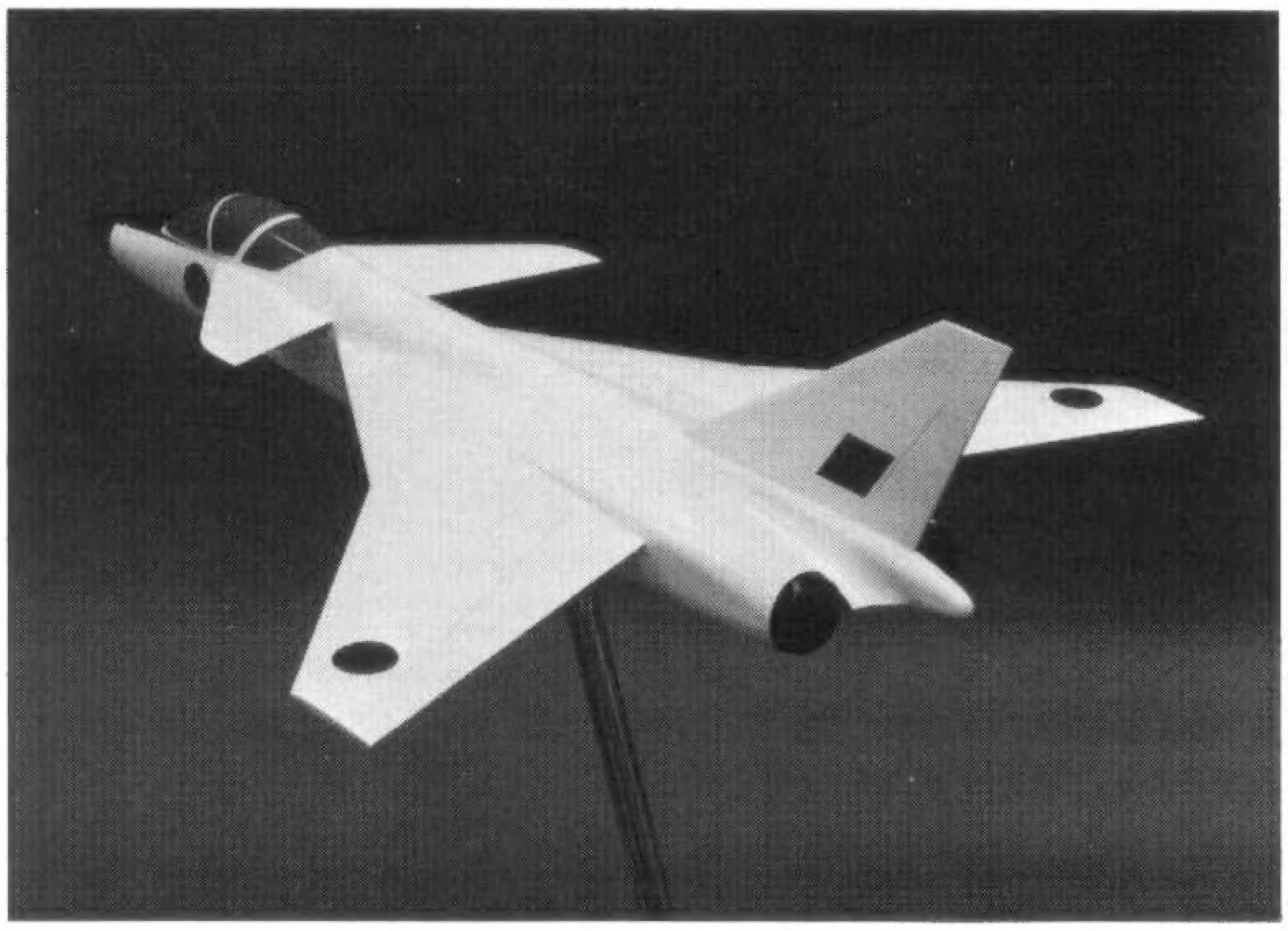
EAP has been created very quickly, but its roots go back almost ten years. It was in the late 1970s that the project staff at British Aerospace at Warton, Lancashire, progressively refined their studies for a new fighter into a twin-engined design with a big centreline fin, large rear delta wings and canards. There was still plenty of uncertainty about even such major features as the location of the canards and the engine inlet(s), but something looking very like today's EAP was on the drawing boards at Warton a decade ago. On the other hand, in engineering detail, and in the general level of technology, the two aircraft would have been very different. The intervening years have by no means been wasted.

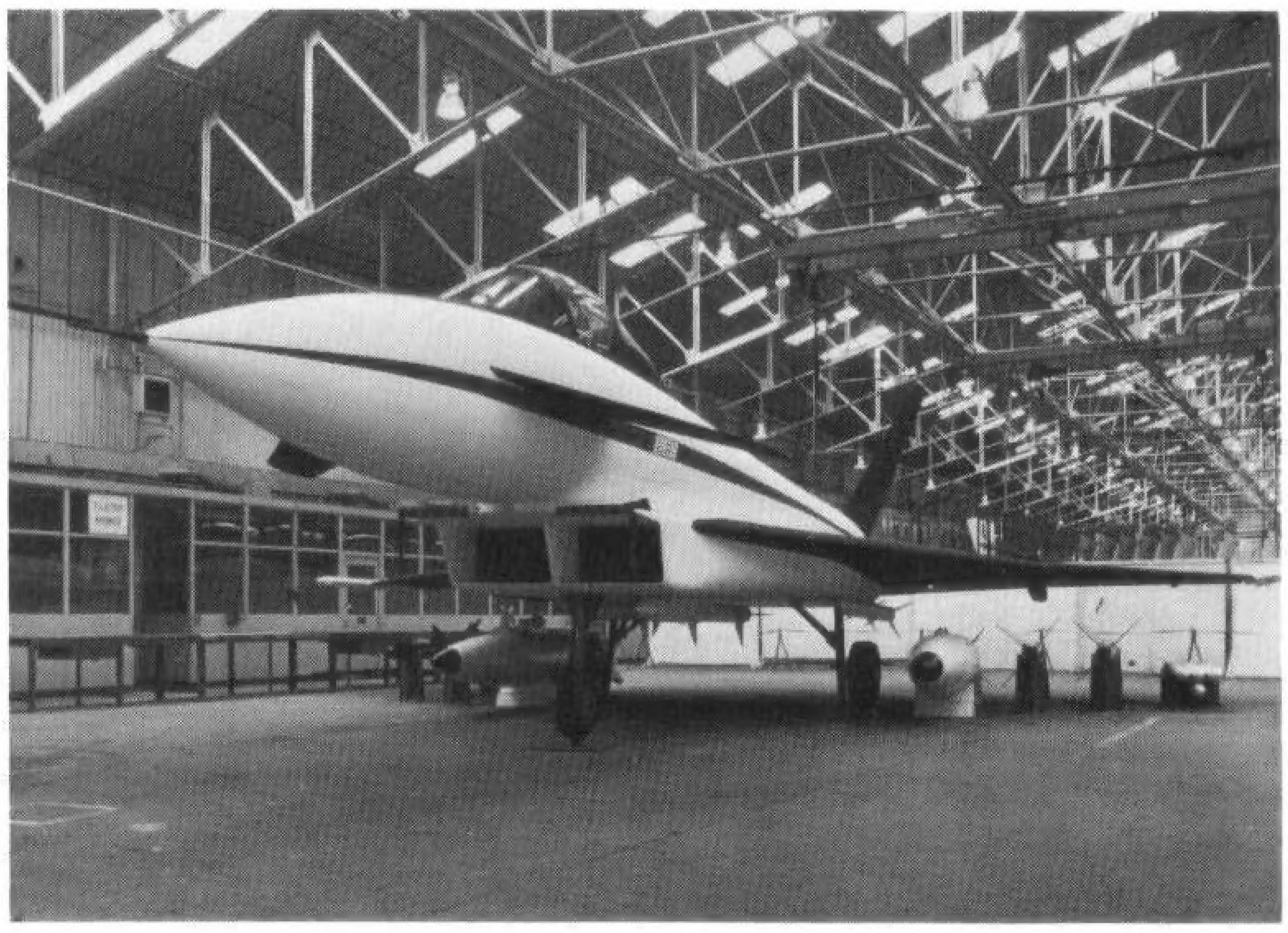
Progenitors of EAP. The BAe P.106 (below left) was a 1980 study for a single-engined agile fighter, designated LCA (Light Combat Aircraft); the P.110 (below right) was a twin-engined parallel study, offered in response to the RAF's requirement for an air-combat fighter and subsequently forming the basis for the collaborative ECA (European Combat Aircraft).

Messerschmitt-Bölkow-Blohm were meantime working on their TKF90 project (bottom left), which would incorporate the company's research into composite structures and unstable layouts. *MBB*

Full BAe/MBB/Aeritalia collaboration was eventually signalled with the emergence of ACA (Agile Combat Aircraft) in 1982 (bottom right), a mock-up of which was produced at Warton and was displayed at the Farnborough Air Show that year.







Partly through Panavia, the trinational management company for the Tornado programme, Warton has for some twenty years had close links with Messerschmitt-Bölkow-Blohm in West Germany and Aeritalia in Italy. These companies also study future fighter designs, and MBB published various proposals under such designations as NKF (*Neue Kampfflugzeug*) and TKF90 (*Taktisches Kampfflugzeug, 1990*). Their thinking became extremely close to that of Warton, and in 1979 a formal joint proposal to the British and German governments was made by the two companies under the title of ECF (European Combat Fighter). Predictably, both governments tried to avoid taking any positive decision by calling for more talks with possible partners. The upshot was that a year later, in 1980, the British and German partners sat down with Dassault-Breguet of France to try to agree a slightly modified design called ECA (European Combat Aircraft). Even between such strongly nationalistic partners the engineers can usually reach agreement, but ECA was doomed by the failure of the discussions between the governments. To some degree this reflected slightly differing views by the customers on what they wanted to buy, and ever since that time the French have emphasised their wish for a fractionally lighter aircraft than that foreseen by the other nations, and also their unique requirement for a carrier-based naval version. In true West European style, this has split the supposed allies, so the uncommitted nations can have fun playing one group off against the other.

In 1981 Warton produced its P.110 project, while almost the same thing appeared at MBB as TKF90. Dornier, working with Northrop, produced its own proposal, and studies continued at Aeritalia. Specialist suppliers also began private studies, and in the UK an IAWG (Industrial Avionics Working Group) was formed by BAe, GEC Avionics, Ferranti and Smiths Industries. Rolls-Royce, which via Turbo-Union builds the Tornado's RB.199 engine in partnership with MTU of West Germany and Fiat of Italy, intensified fighter engine studies which involved special core demonstrators and finally a new engine proposal, the XG-40.

In April 1982 BAe, MBB and Aeritalia, the three members of Panavia, at last merged their ideas and came up with a joint proposal called ACA (Agile Combat Aircraft). A mock-up appeared on the BAe stand at the 1982 Farnborough show, where it was announced that government support would be forthcoming for a demonstrator to be called the EAP (Experimental Aircraft Programme) with a first flight predicted for 30 April 1986. It was blindingly obvious that the three governments should get the project off to a proper start,▸

A number of artist's impressions of EAP appeared between the time the project was agreed and the emergence of the actual aircraft. One of the first (below left) retained the ACA livery. A later piece of artwork (below right) showed that a decision had been made to move the wing-tip missile stations fractionally inboard, whilst a third (bottom left) showed a recontoured fin. EAP as completed is shown bottom right.

EAP poses for the photographer at a rain-swept Warton a few weeks prior to its first flight (left). A row of ex-Saudi Lightning interceptors – also designed and built at Warton – stand as silent sentinels in the background.

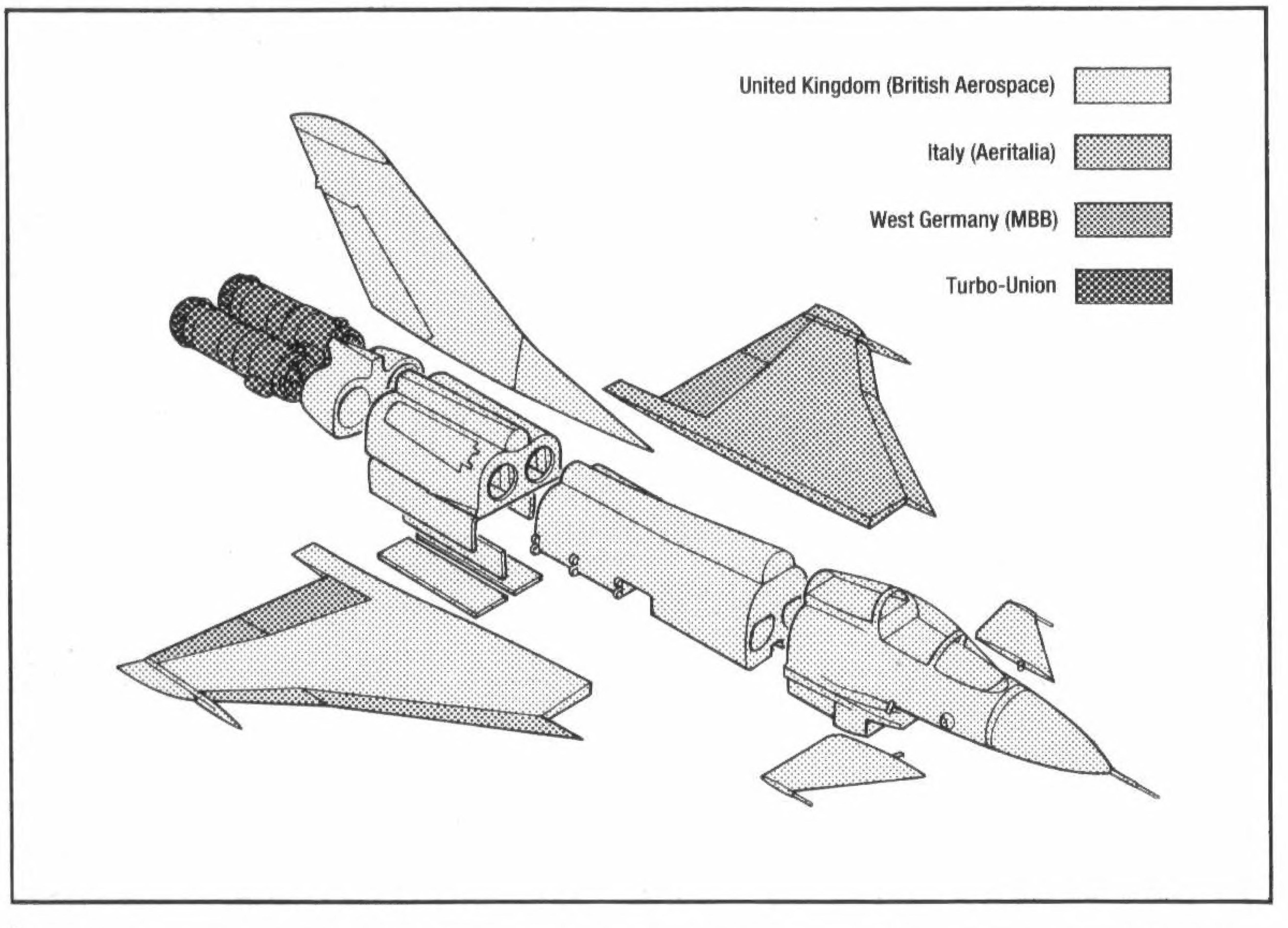
EAP personalities: (left to right) John Vincent, Executive Director EAP/EFA; David Eagles, Executive Director Flight Operations; Tony Baxter, Director and General Manager Warton/Samlesbury/Preston; and Brian Young, Divisional Technical Director.

UNITED KINGDOM
AP Precision
Aeroquip
APME
Avica
Bestobell
BAe Electronic Systems and Equipment Division
BAe Air Weapons Division
Chelton
Cossor
Dowty-Boulton Paul
Dowty Electrics
Dowty Rotol
Druck
Dunlop
Fairey
Ferranti
Flight Refuelling
GEC Avionics
Gloster Saro
Graviner
High Temp Engineering
Hymatic
Irvin
Lucas Aerospace
ML Aviation
Marston Palmer
Martin-Baker
NGL
Negretti and Zambra
Page
Plessey
Racal
ROF
Rosemount
Saft (UK) Ltd
Smiths
Turbo Union
Vickers Systems

GERMANY
AOA
BGT
Eichweber
Electro-Metall
ETA
Feinmechanische Werke Mainz
KST
LITEF
Leach Relais
Liebherr
MBB
Nordmicro
Pierburg
Teldix
Teves
VDO
Westfalische Metal Industrie
ZF

ITALY
AIT GEq
FIMAC
Itala
Italtel
Magnaghi
Microtecnica
Nardi
OMA
Ribali
Secondo Mona

The production of actual hardware in the shape of EAP has only been possible because of a unique collaborative effort involving literally dozens of contributing suppliers who are donating their services and components to the programme at their own expense. The listing in the panel at left shows the main companies involved, but many other concerns have made significant contributions.



The international flavour of the Experimental Aircraft Programme can be gauged from this drawing. Turbo-Union is itself an international company, comprising Rolls-Royce, Motoren und Turbinen-Union (MTU) of West Germany and Fiat of Italy.

with at least one EAP prototype in each country and with an agreed work-split. Tragically, for reasons which ought to be made public, the decision-takers in Bonn and Rome decided to pull out. This has prevented any proper work-sharing, cut the programme to a single aircraft and forced that aircraft to be regarded not as a prototype but as a mere demonstrator of some advanced ideas.

It is to the great and enduring credit of British industry that the EAP has not only survived but has been created on time and within budget. Indeed, the fewer customers and governments can meddle in a project, the better it is and the faster it makes progress. On the other hand, EAP is very far from being a mere national creation. Despite the pathetic indecision of their own governments, the industries of West Germany and Italy have also played a major role in the production of the EAP. Major contributors are listed separately. Aeritalia made the left wing, in a share of about 15 per cent, whilst MBB, who would have made the rear fuselage and fin, have a nominal 1 per cent share to keep a tenuous foot in the door. But the real strength has come from the many suppliers in all three countries who accepted Warton's invitation to design and build thousands of vital parts without charge. Their hoped-for reward will be to do the same in the future EFA (European Fighter Aircraft) production programme. But as this book is written, nobody dare say what the Eurofighter might be like, beyond the fact that it will be derived from the EAP and that drawings of a possible EFA look similar. In June 1986 a new company, formed to create the EFA, was registered in Munich. Called Eurofighter Jagdflugzeug GmbH, it is owned by BAe, MBB, Aeritalia and CASA.

The first truly public demonstration of EAP was at the 1986 Farnborough Air Show, where the aircraft put on a stunning flying display (above).

British Aerospace's initial design submission for the European Fighter Aircraft (EFA) programme (below). Its affinity with EAP in terms of looks hardly needs comment!

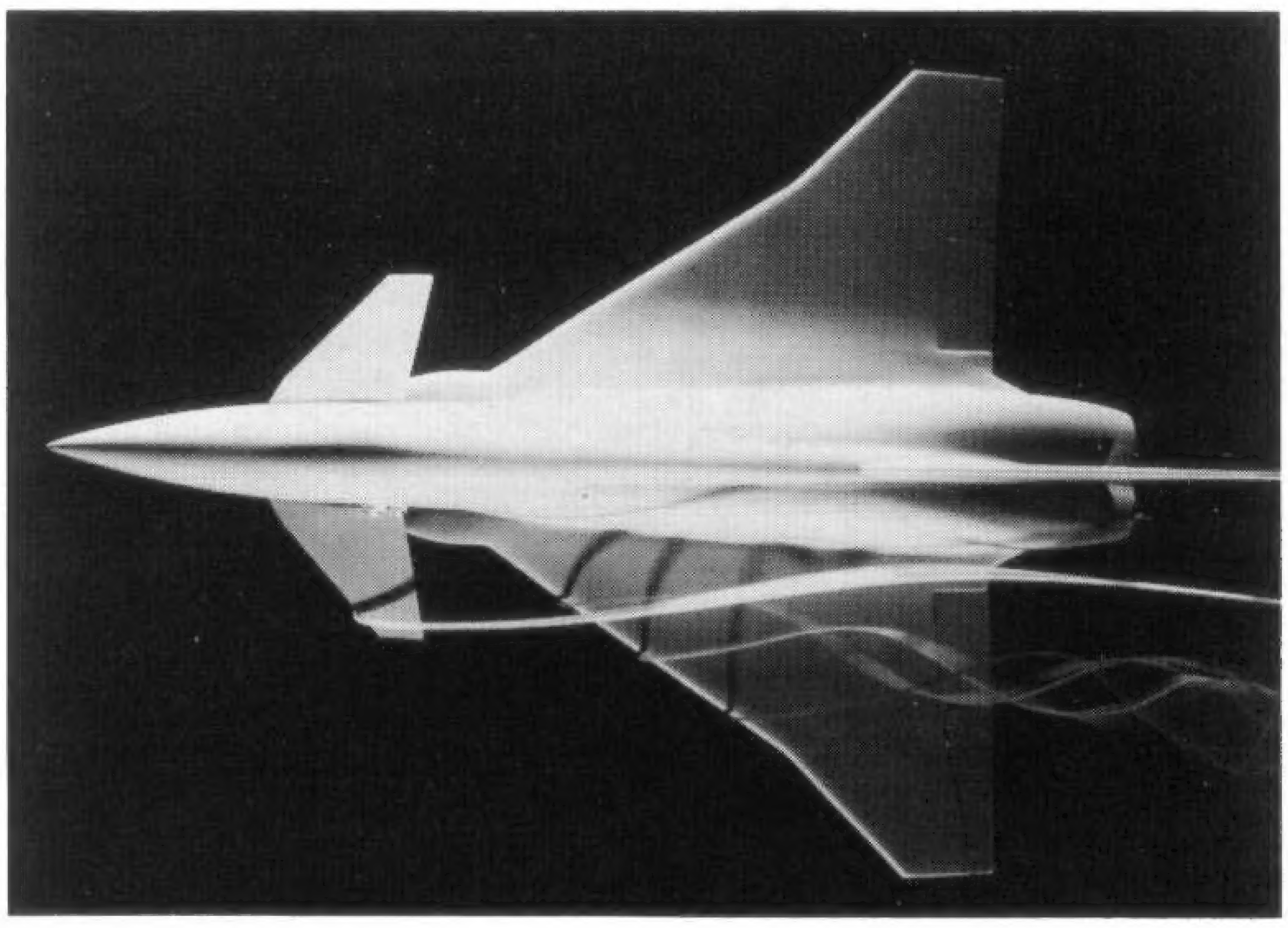
DESIGN & STRUCTURE

The EAP was designed at Warton as a refinement of the trinational ACA. BAe takes pains to point out that it is not a fighter and not even a prototype, but merely that it 'has the size and performance of an air-superiority aircraft'. For obvious reasons of cost and timing it incorporates compromises that would not be made in a future EFA, one of these being its RB.199 engines and another its modified Tornado vertical tail. Again, the refusal of the West German government to provide funding resulted in BAe building a light-alloy centre and rear fuselage; MBB had planned to contribute these sections in CFRP (carbon-fibre reinforced plastics) and SPF/DB (superplastic-formed and diffusion-bonded) titanium, and BAe were forced to switch to older methods in order to meet the schedule and the budget. In the same way, other items such as an APU (auxiliary power unit) were omitted from this single demonstrator – which is not expected ever to go far from BAe airfields.

The EAP's objectives are listed in the accompanying panel, but in essence the aircraft has been designed to lead to a fighter for both BVR (beyond visual range) kill using Advanced Medium-Range Air-to-Air Missiles (AMRAAM) and close combat using short-range air-to-air missiles (SRAAM). To meet these demands fully calls for almost every performance requirement in the book, other than low-level ride quality – and even this is also to be demonstrated, in order to give a future EFA a ground attack capability. In a nutshell, EAP, in comparison with its rivals, needs more wing area, less weight, more engine thrust, greater manoeuvrability and less drag at subsonic and supersonic speeds, shorter field length, and virtually every other conceivable attribute.

Like all modern air-combat aircraft, EAP has been designed to be basically unstable. BAe Warton is one of the world leaders in such technology with the ACT (active control technology) Jaguar. This has a 660lb weight in the rear fuselage and large forward▶

Warton's ACT Jaguar (below left) has provided invaluable data for the design of successful unstable aircraft, whilst wind-tunnel models (below right) have of course been employed to prove optimum aerodynamic layouts for EAP. To save time and money, a tailfin adapted from the type fitted to a Tornado (bottom) was adopted.



EAP OBJECTIVES

1 Advanced structures and materials
The ability of industry to design and manufacture in advanced materials airworthy primary structures such as wings canards and fins using manufacturing techniques that could be readily assessed to determine how they might evolve in a production context.

2 Aerodynamics
High angle of attack (AOA) flight at moderate speed; the use of a departure prevention system at high AOAs and low speeds, a control system design for non-linear interference involving canards, wing flaps and fins, transonic acceleration and supersonic flight low-level ride quality airfield performance, particularly landing, intake behaviour at high AOAs and its effect on engine performance: and configuration design for low-drag weapon carriage

3. Active control technology (ACT)
The application of a full-authority digital fly-by-wire (FBW) system to a highly unstable aircraft, in particular one using canards, the computer to be flexible enough to facilitate control law optimisation

4 Digital data bus
A digital data bus avionics system incorporating a 'core' avionics system

5. Modern cockpit design
The cockpit shall utilise technology that gives a capability representative of modern designs

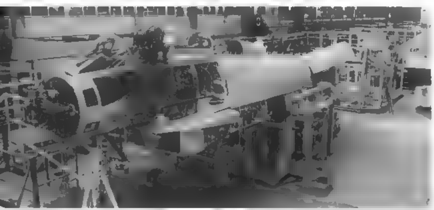
6. Stealth
A demonstration of the ability to design an aircraft with low radar and infra-red (IR) signatures

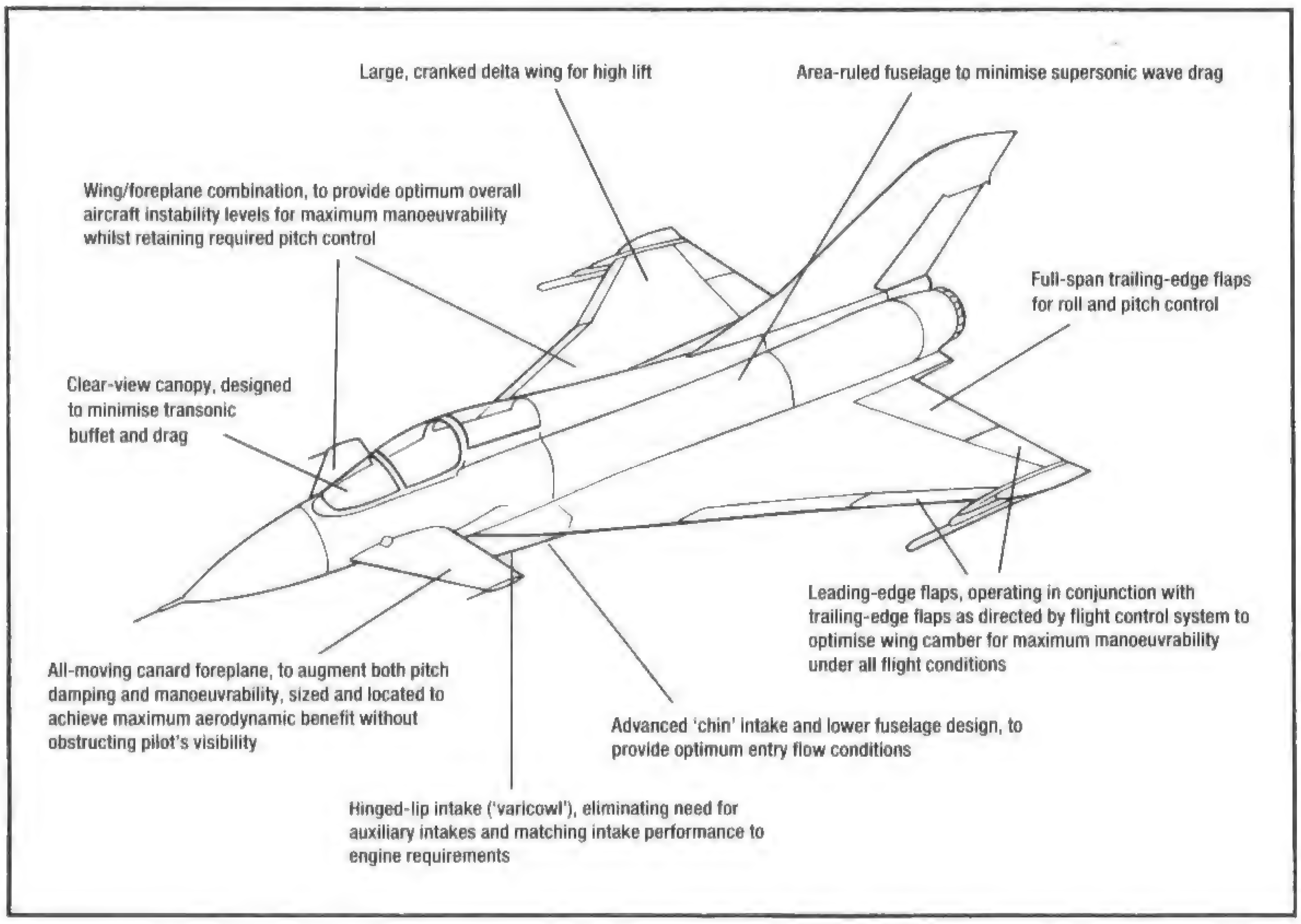
7 Digital control of engine
The existing Advanced Military Demonstrator (AMD) encompassing full-authority digital engine control (FADEC) should demonstrate digital control of engines

EAP is not a fighter nor (technically) is it a prototype. Like the X-29 across the Atlantic it is a demonstrator tasked with proving new concepts listed at left

BAe Warton Division's Samlesbury clean room facility where the manufacture and co-bonding of the torsion box for the starboard wing were undertaken

The fuselage takes shape. The aircraft's fin can be seen in the right background. Note that the cockpit head-up display (HUD) unit and ejection seat are already in place



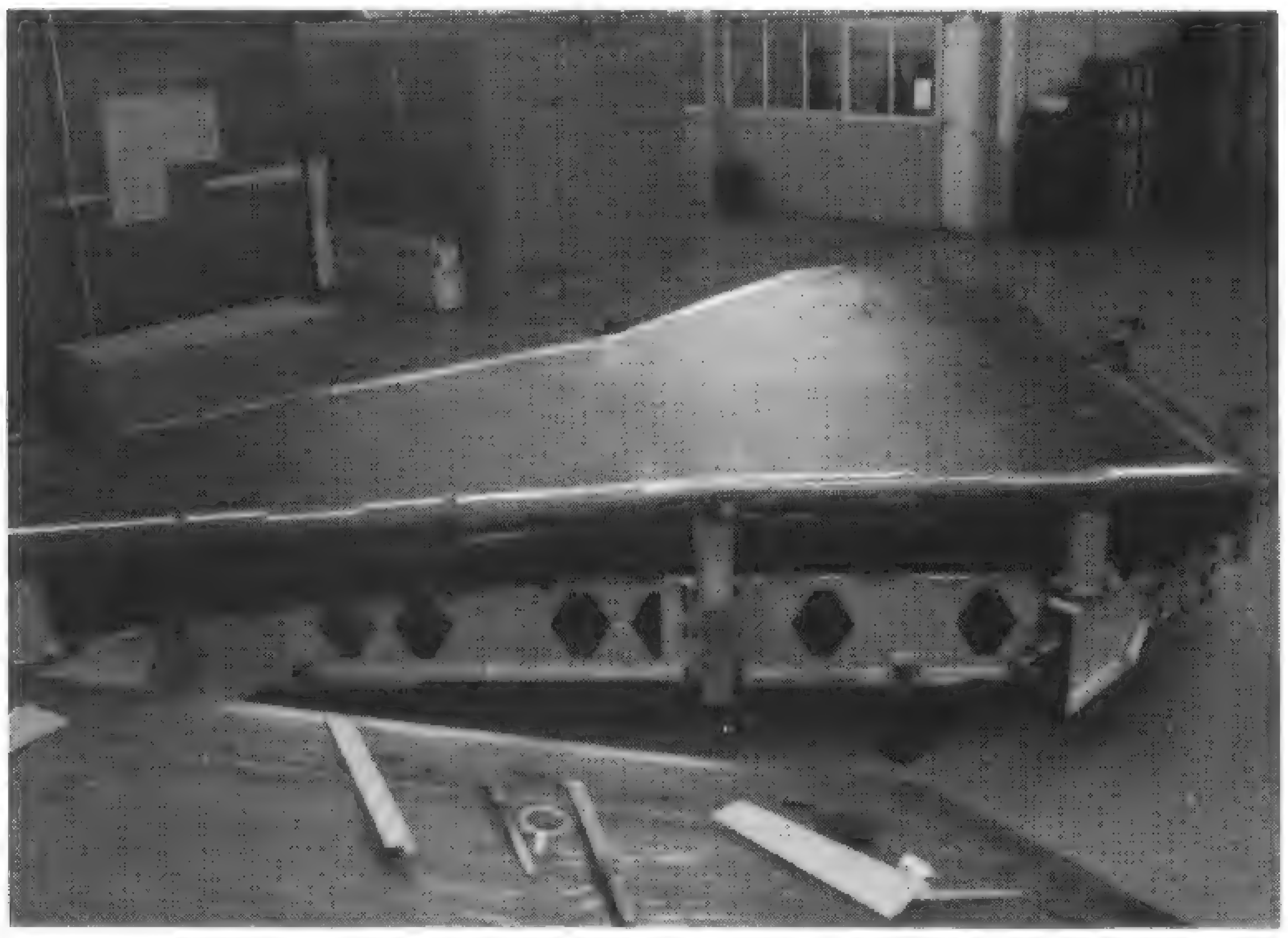


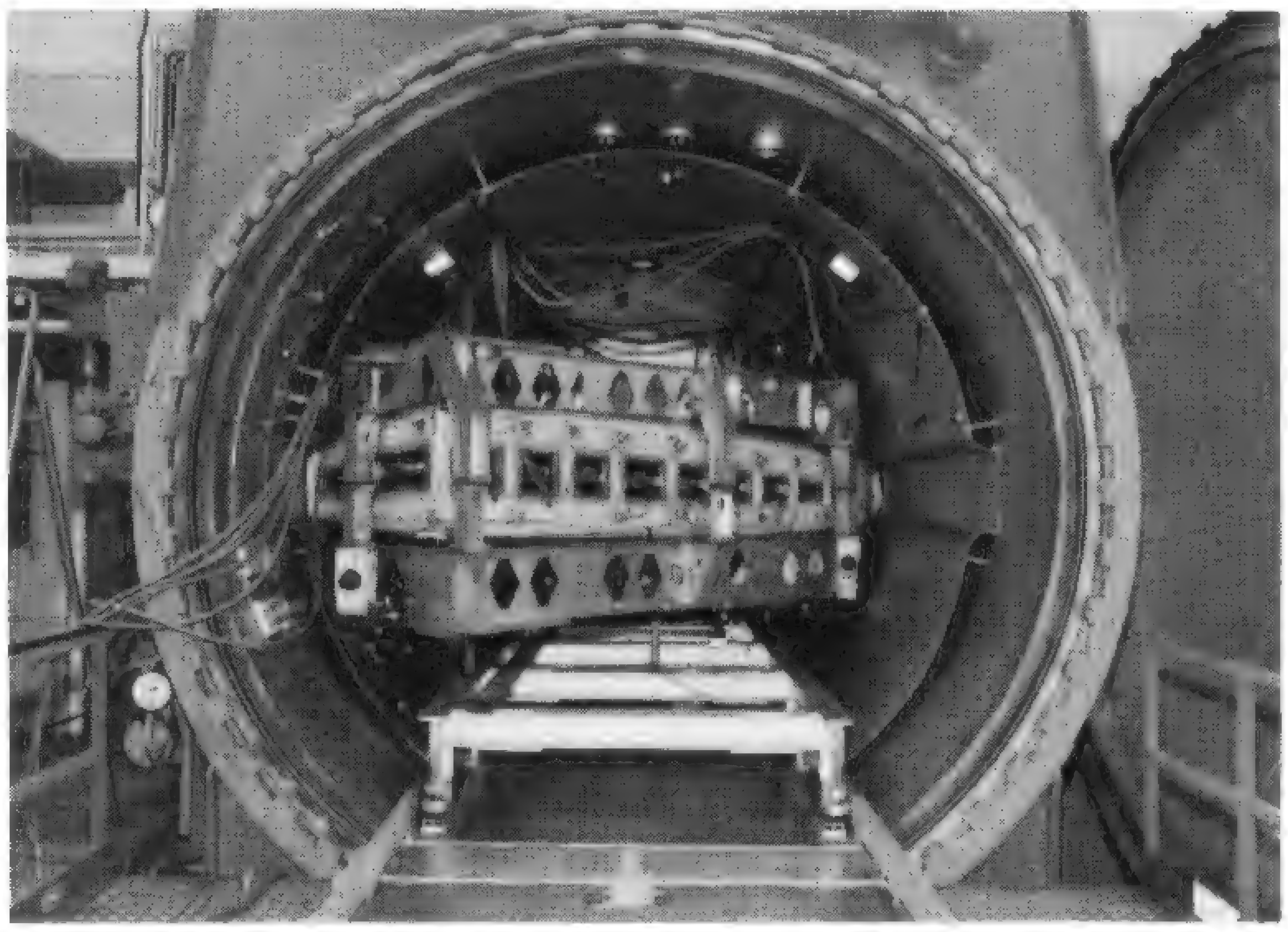
A drawing illustrating the key aerodynamic features of the EAP design.

extensions to the wing roots to give a pitch instability of 10 per cent. To fly the aircraft a fast computer translates pilot demands into suitable outputs, limited in magnitude so that they can never overstress the aircraft and fed to a quadruplex sensing and duo-triplex actuation system guaranteeing a failure rate not higher than once in every million flight hours. A similar arrangement is fitted to EAP, but here the challenges are much greater. Instability exceeds 15 per cent and there are thirteen separate movable surfaces to be controlled, so the FCCs (flight-control computers) have to work more than three times as fast as those of the ACT Jaguar. Flying the latter was described as 'like steering a bicycle pushed rear-end first by the handlebars whilst sitting on the front of a 60mph car'; flying EAP is like steering the same reversed bike at 180mph.

Avionics are considered in a separate chapter, wherein it is explained that almost every functioning item in the aircraft is linked into the databus. Major branches off the bus run the flight-controls. Perhaps the most impressive single feature of the EAP is the wing, with its compound-swept delta shape, streamwise tips and constant subtle changes in curvature and profile from root to tip. Almost the entire leading and trailing edges are hinged to give infinitely variable camber according to airspeed and AOA (angle of attack) to achieve the maximum lift/drag ratio throughout flight. The trailing controls are flaperons, operating in pitch in partnership with the canards under the control of the FCCs to give totally 'carefree' manoeuvring under all conditions. Roll control is by the four flaperons only, the two outers being locked inoperative at high supersonic speeds. The single fin would permit the eventual use of reverse or vectored thrust. On each side of it are the giant airbrakes, and immediately below the rudder is the braking parachute.

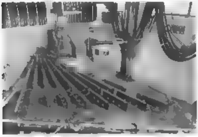
EAP wing technology (1): pre-cured lower wing skin, ready to be mated with the pre-formed, uncured spars (below left), which is then fitted with the upper skin and tool and co-bonded in an autoclave (below right).

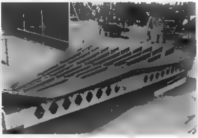


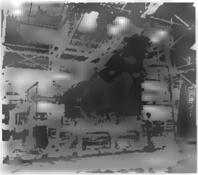


Like the Grumman X-29, subject of a companion book, the EAP has a CFRP wing that is aeroelastically tailored so that as it deforms under aerodynamic loads, it flexes in the ideal way for minimum drag, with no tendency towards structural divergence. Probably no wing in history has ever had such subtle curvature, and the skins comprise CFRP laminates arranged with their plies aligned in precise but sharply differing directions to give optimum flexure, the number of layers increasing from the tip to about 200 at the root. The lower skin is co-bonded to the multiple CFRP spars to become a single piece of structure forming an integral tank and with three hardpoints for pylons on each side excluding the AAM pylon near the tip. The pre-formed upper skin is then attached by removable screws and bolts. ▶

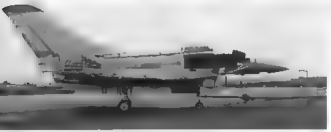
EAP wing technology (2): the Aeritalia-produced port wing (lower skin panel plus spars) undergoes checks (below left), and the BAe-manufactured starboard wing assembly ready for testing (below right)



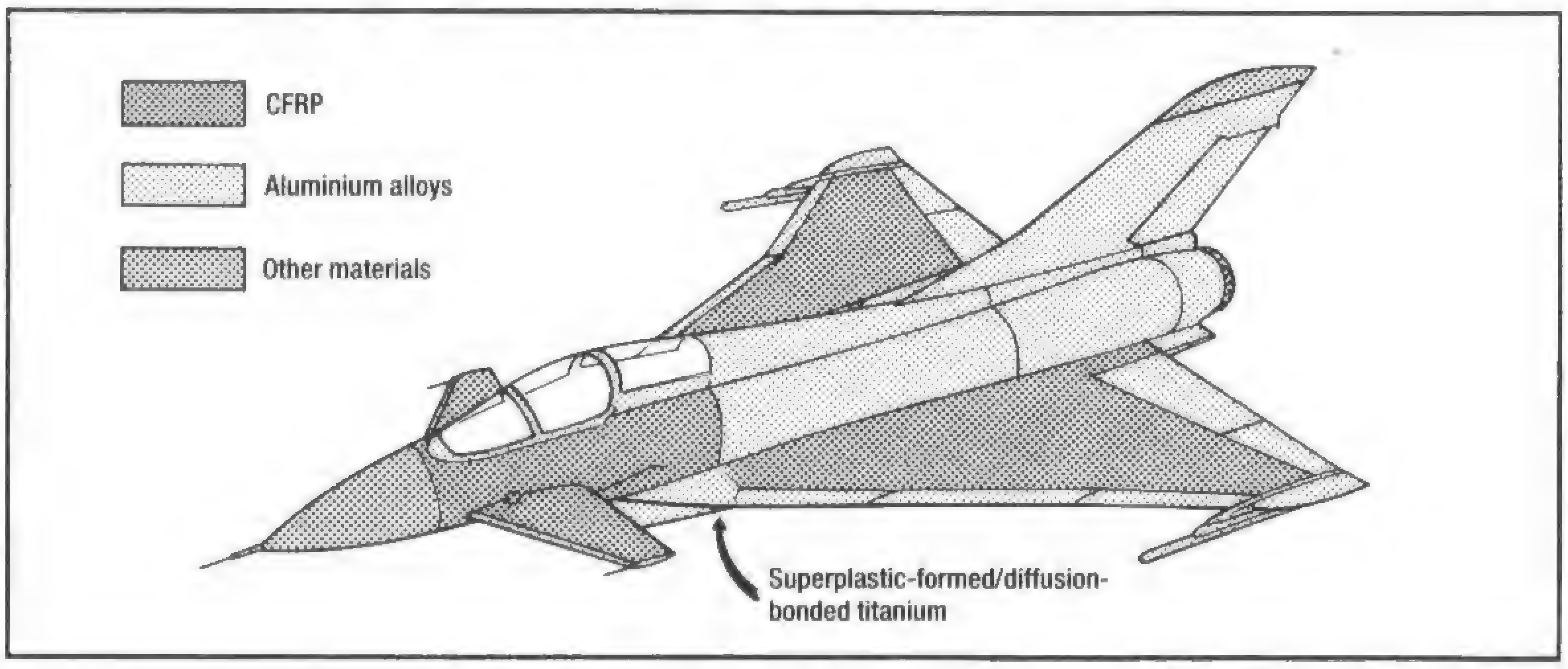




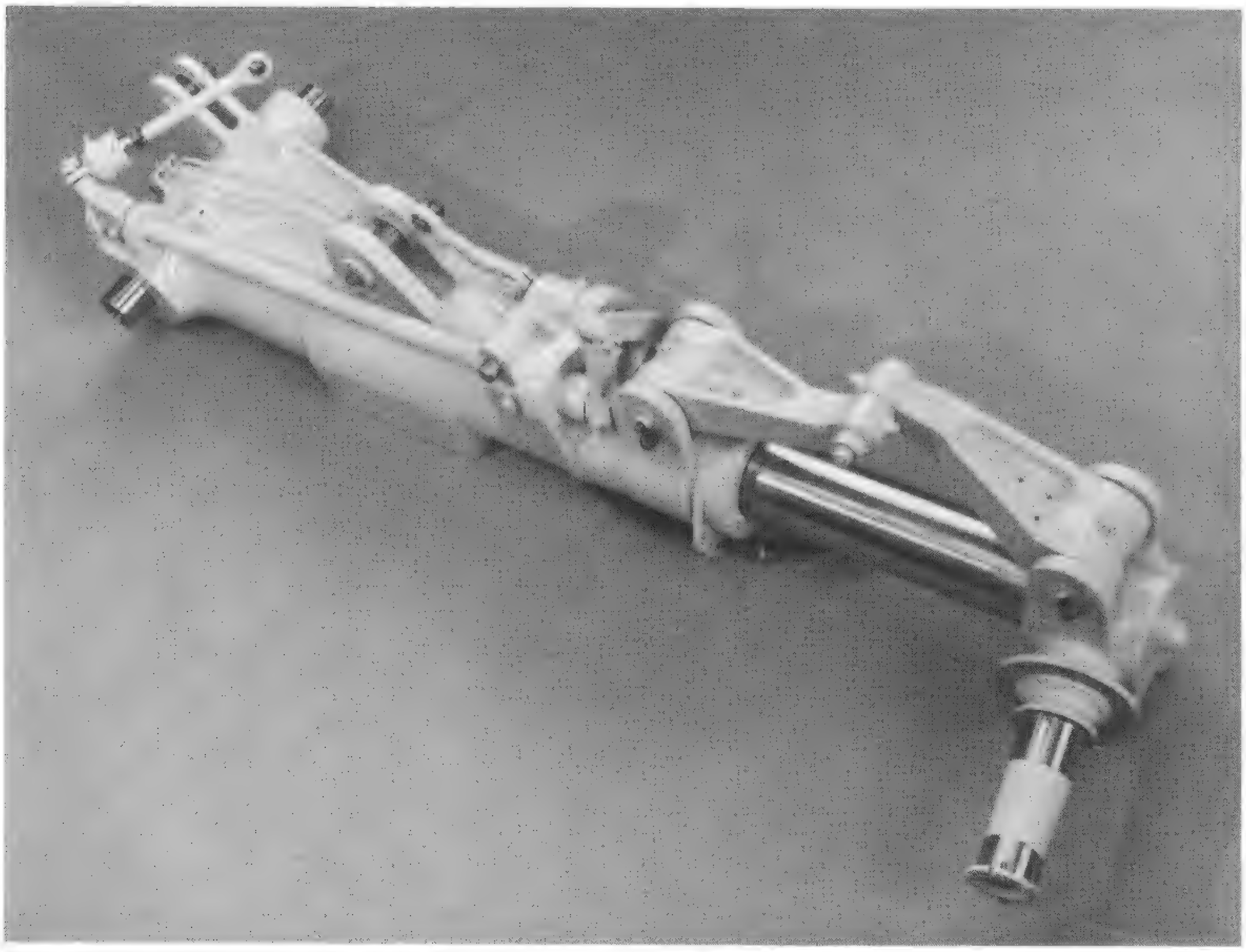
EAP wing technology (3): Starboard wing just prior to fit of upper wing skin (above left), and mating of upper skin in its assembly jig (above right)



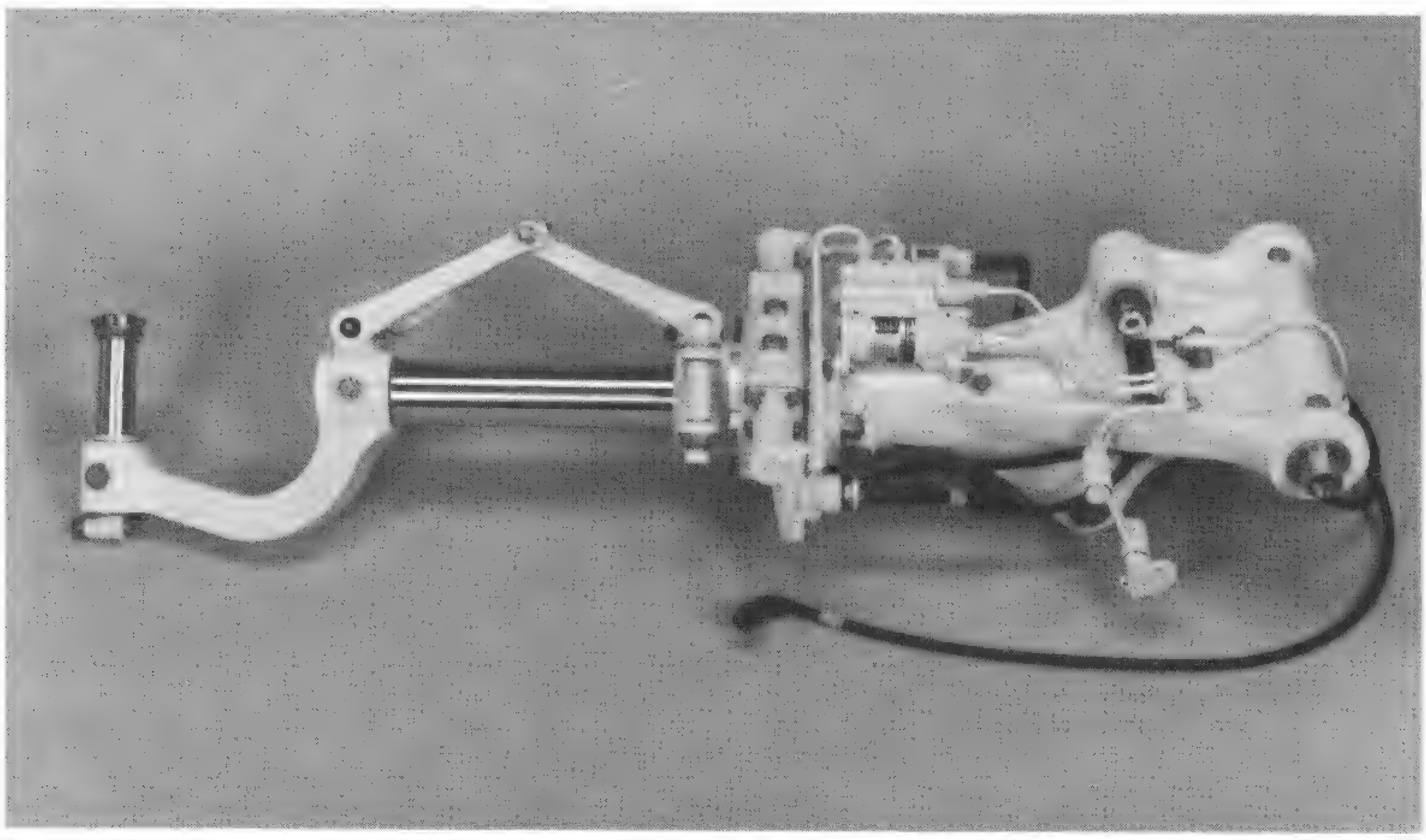
On 27 October 1985 the aircraft was structurally almost complete when it was moved out of the assembly hall for calibration tests



Not least amongst the novel technologies being demonstrated in EAP is the use of advanced materials such as CFRP and aluminium/lithium alloys (left).



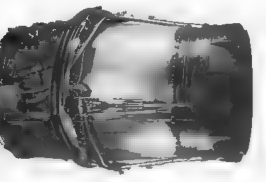
Leading UK companies have put in a great effort for the programme. Dowty Rotol, for example, is the lead supplier for the landing gear, in partnership with Nardi and Liebherr. Pictured left is the starboard main gear unit, the photo below showing the nose gear leg. *Dowty Group*



A cutaway drawing showing the principal systems in EAP (right).

Each wing is attached at the root to the fuselage with three forged titanium plates, the spars passing straight across under the fuselage. Ahead of the CFRP root on each side is a large apex extension made of light alloy with CFRP skins. The leading-edge flaps are aluminium alloy, driven by rotary actuators. The flaperon skins are machined aluminium-lithium alloy.

The wing apex is extended forward to form a flat, ogival splitter plate above the engine inlet. As on the MiG-29, this plays a major role in guiding clean air into the inlet under AOAs up to 30 degrees. The only movable part of the inlet is the lower lip, which forms a large hinged 'varicowl' which automatically rises and falls to adjust inlet profile and area to all flight conditions. The whole bay behind the cockpit and above the inlet is occupied by avionics and the ECS (environmental control system). The steerable nose landing gear is mounted just aft of the varicowl and retracts aft between the upward-sloping ducts. The simple main undercarriage units are pivoted to the sides of the fuselage under the wing and retract forwards, each wheel lying flat under the engine air duct. Navigation lights are carried on each side of the fin tip, inside transparent sections of the inboard leading-edge flap, and in the fronts of the outer-wing missile pylon adapters.



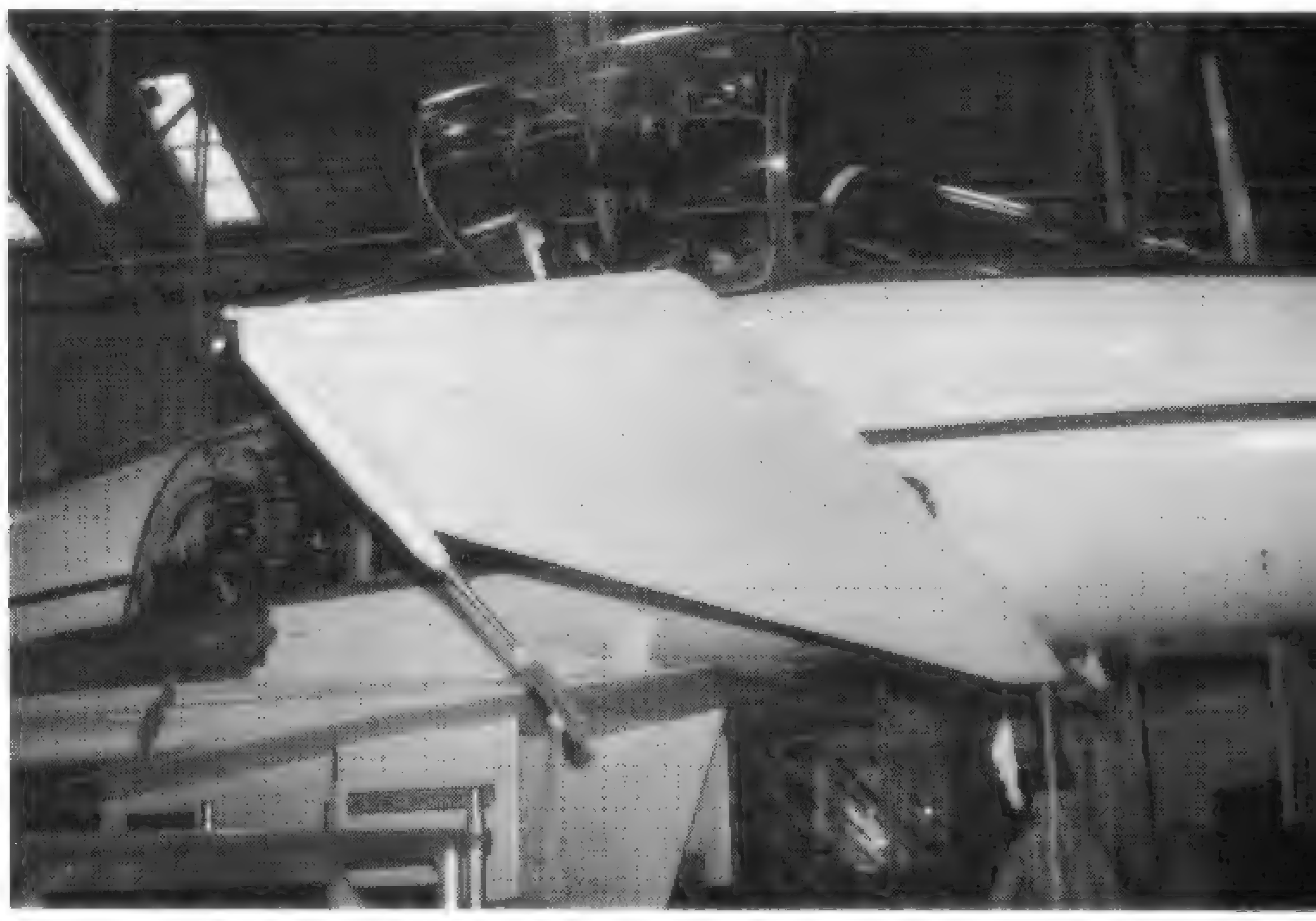
Lucas Aerospace has also played an important part in bringing EAP to fruition, furnishing a number of systems including the nozzle actuator mechanism for the RB.199 powerplants (left). The air motor drive unit can be seen to the far left of the photo, and from this a tube and flexible sheath carrying the drive shafts encircle the jet pipe, from which actuators connecting with the nozzle shroud are led off. *Lucas Aerospace*

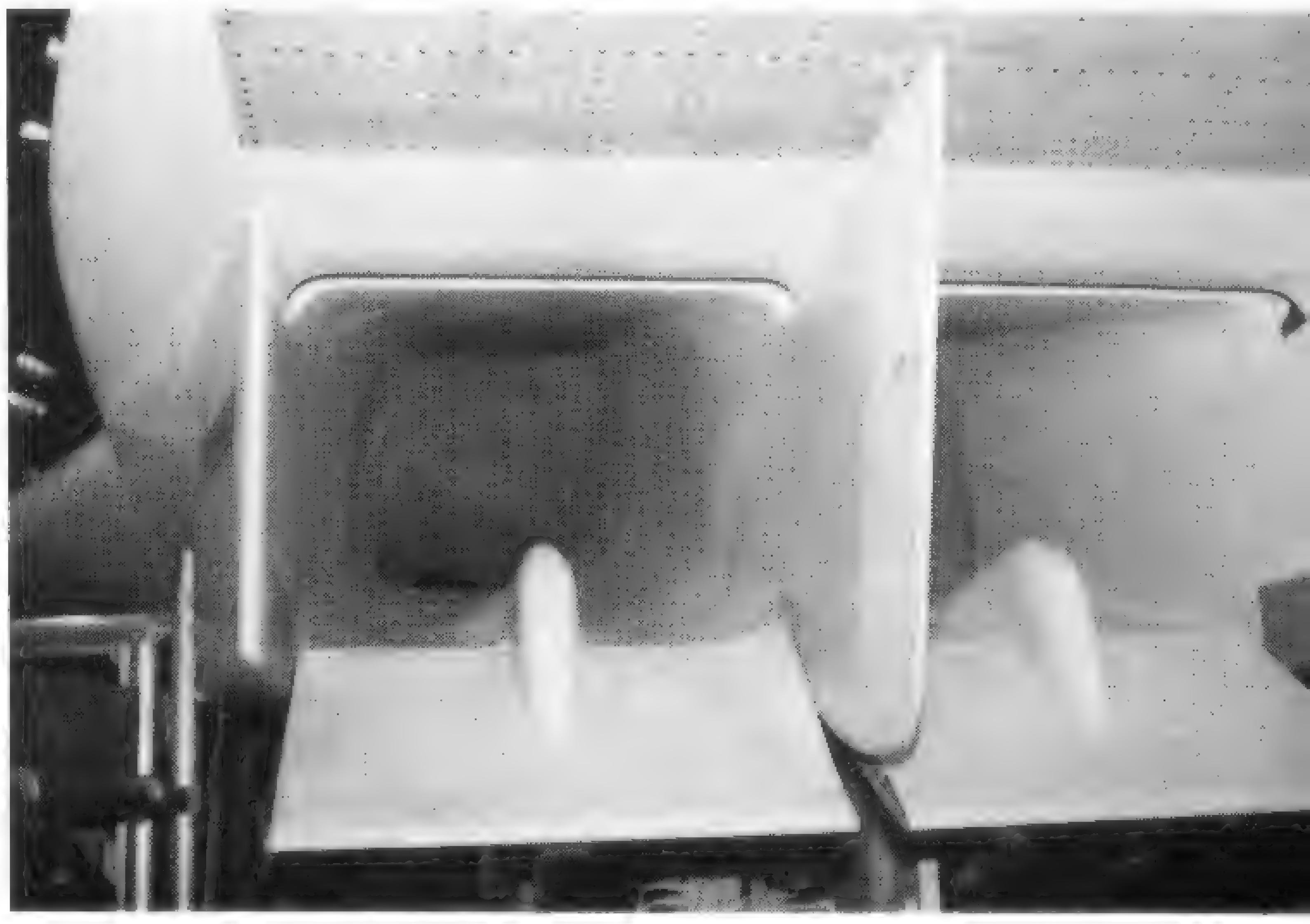
Key

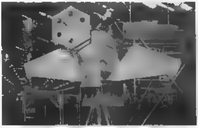
1. Forward equipment cooling duct
2. Flight test instrumentation
3. Airstream direction detector probes
4. IFF aerials
5. Air data computer
6. Video sensing head
7. Rudder pedals
8. Head-up display
9. Multifunction displays
10. Canard foreplane spigot
11. Canard actuator
12. Control column
13. Side console
14. LOX (liquid oxygen) converter
15. Intake support strut
16. Martin-Baker Mk 10LX ejection seat
17. Flight control computers
18. Intercooler
19. Aircraft motion sensor units (4)
20. Intake duct
21. UHF aerial
22. Fatigue meter
23. Fuselage fuel tanks (14)
24. Anti-collision light
25. Engine air bleed ducts
26. Hydraulic accumulator
27. Air brake actuator
28. Vortex generators
29. Fuel vent valve
30. VHF aerial
31. Rudder actuator
32. Brake parachute housing
33. Navigation light
34. Turbo-Union RB.199 Mk 104D turbofan
35. Inboard flaperon actuator
36. Starboard rear 'Sky Flash' missile
37. Mainplane fuel tank
38. Main undercarriage door (rear)
39. Main undercarriage door (forward)
40. Starboard forward 'Sky Flash' missile
41. Nose undercarriage door
42. Fuel filler (port side only)
43. 'Varicowl' actuator

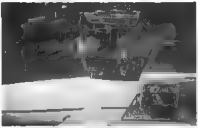
EAP slows to a halt after touch-down (right). Notice that the foreplanes are tilted 80 degrees, doubtless acting as effective air brakes during taxiing.

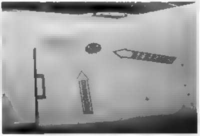
EAP in close-up (1). The canard foreplanes and 'varicowl' main inlet are depicted below.
Note, in the photographs on this spread, the protective box for the delicate vanes on the nose probe and the open avionics and FCC bays. The miniature detonating cord (MDC) in the cockpit canopy glazing can also be seen. *Linewrights*

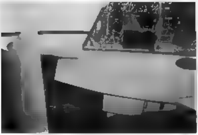








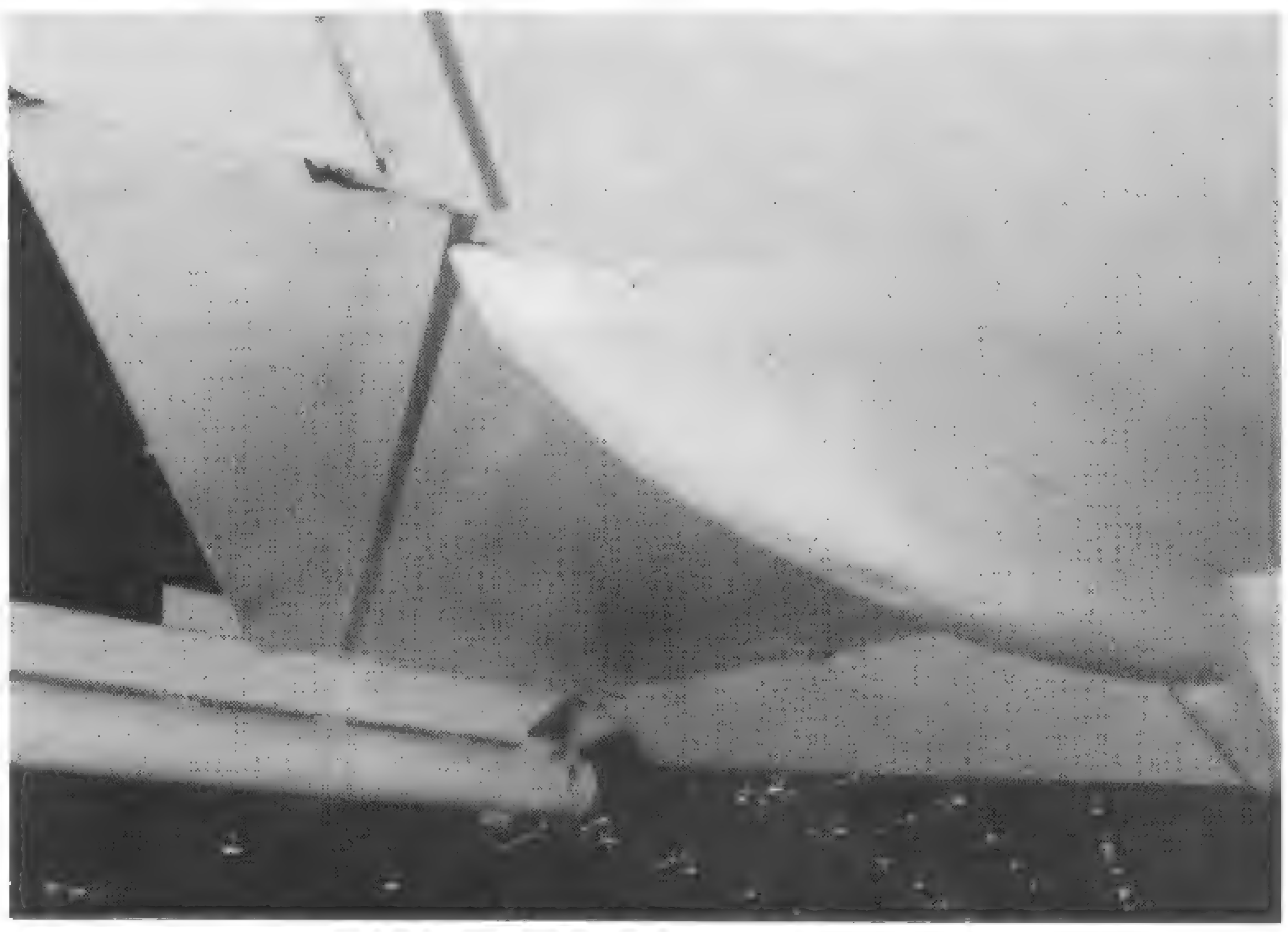


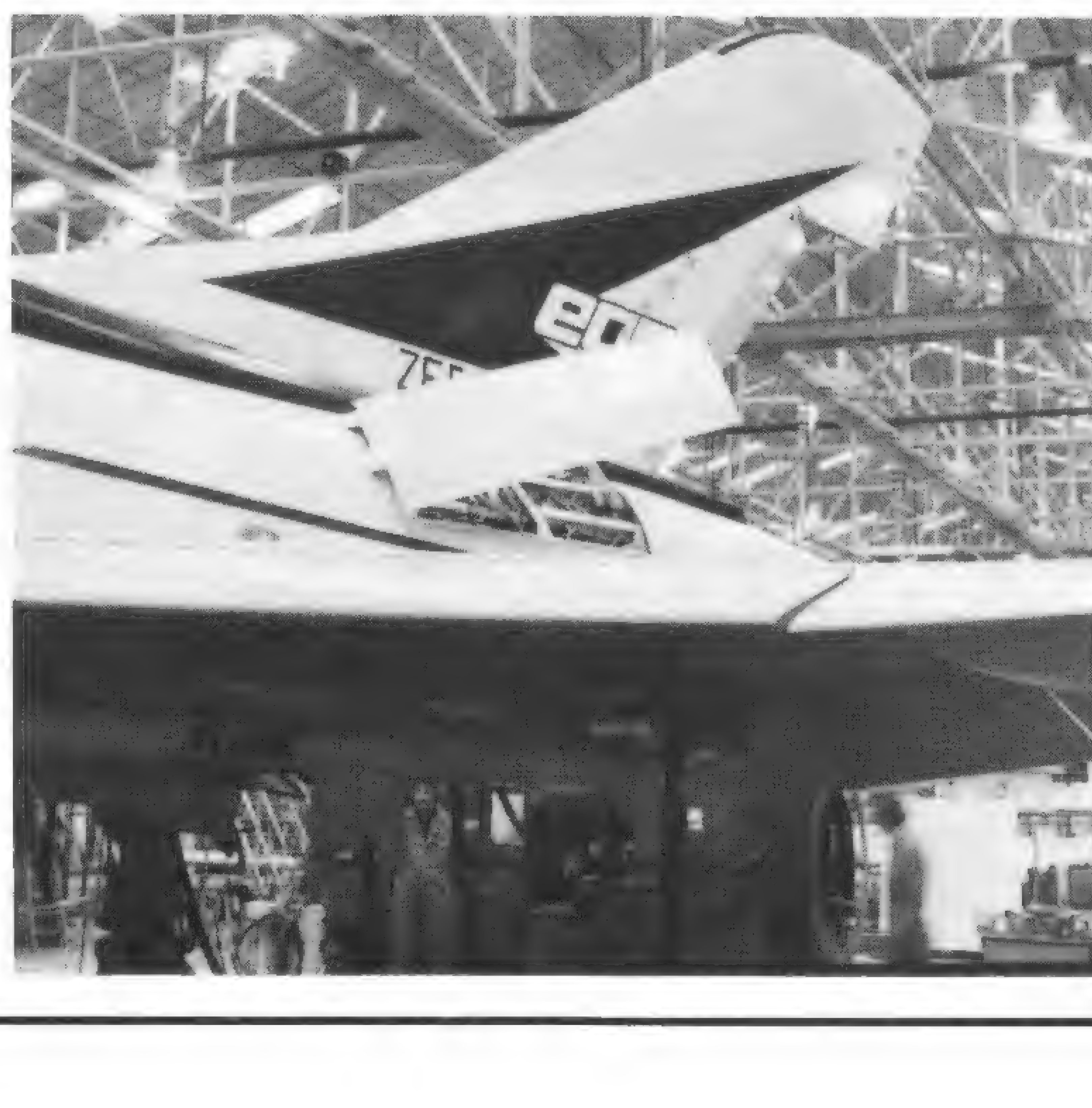


EAP in close-up (2). Note the protective covers with RBF tags for the engine nozzles, the flap actuator fairing and the low-drag pylons for the dummy AAMs. The small tabs down the vertical fin are vortex generators, present also on the Tornado's tail. *Linewrights*

The use of CFRP on the EAP airframe is apparent in the photo opposite top, particularly for the fuselage skinning around the cockpit area.

EAP's official unveiling took place on 16 April 1986 in a futuristic atmosphere, amid a dramatic laser/audio display (opposite bottom).



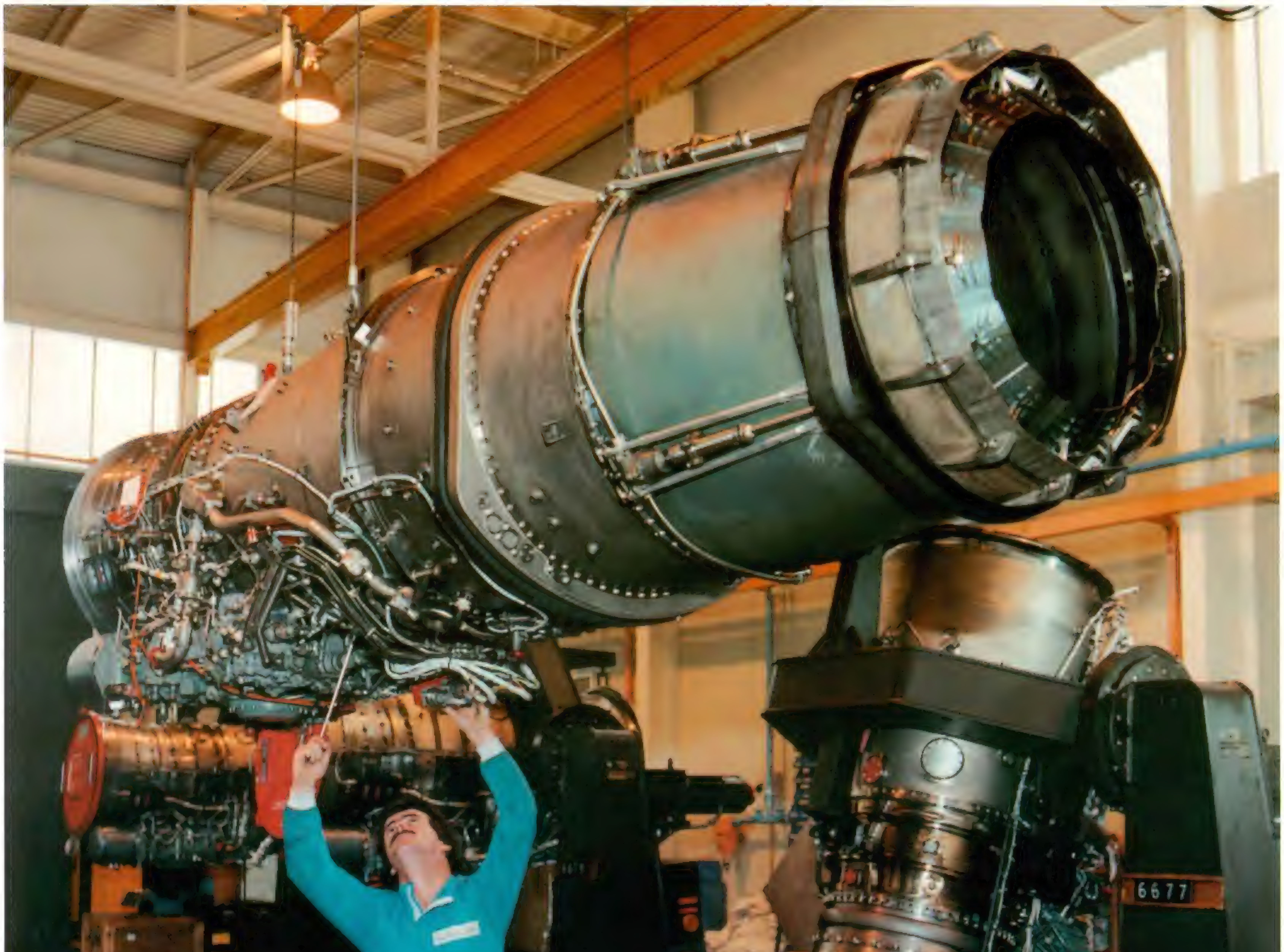



RITISH
AEROSPACE
EAP

Afterburners blazing, EAP leaves Warton Aerodrome for the first time, 3.47pm, 8 August 1986 (right). The aircraft went supersonic on its maiden flight, notching up Mach 1.1 at 30,000ft.

Cruising above light cloud, EAP rides high on her first flight (below). The serenity of the scene belies the intense concentration of test pilot Dave Eagles.

Undercarriage down, the aircraft passes low overhead (far right), showing to perfection the layout of the four dummy Sky Flash and two wing-tip ASRAAMs.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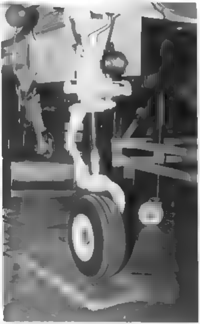
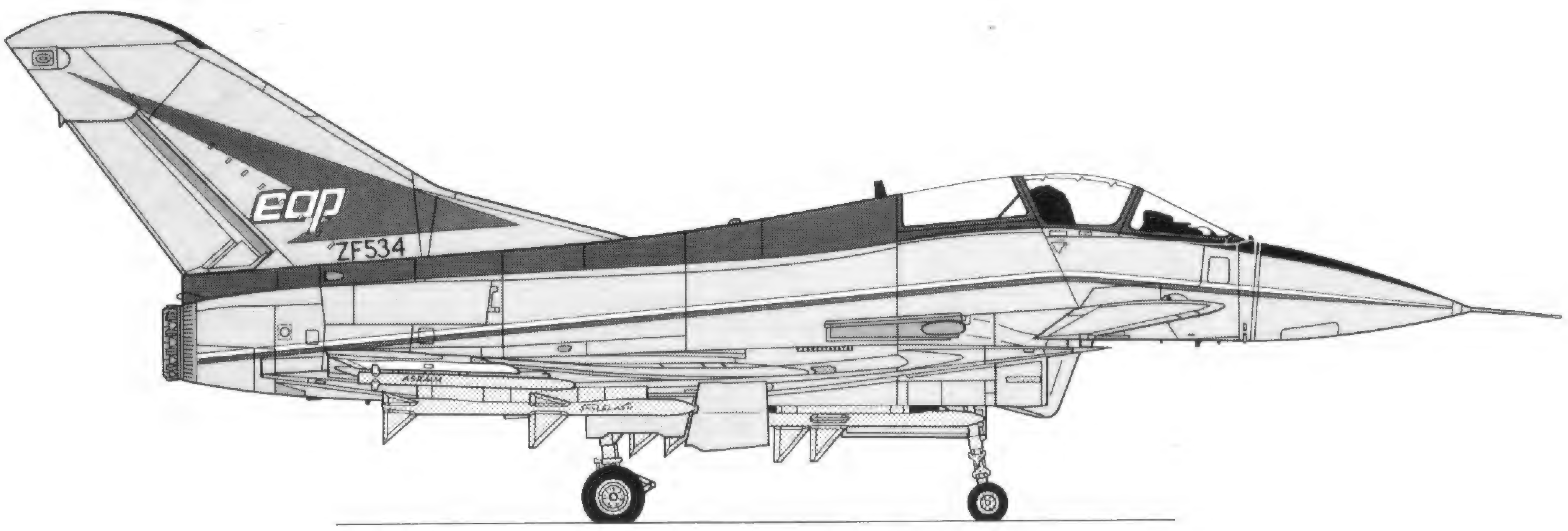
EAP at altitude, 8 August 1986 (opposite, top): the aircraft's remarkably smooth lines readily obvious.

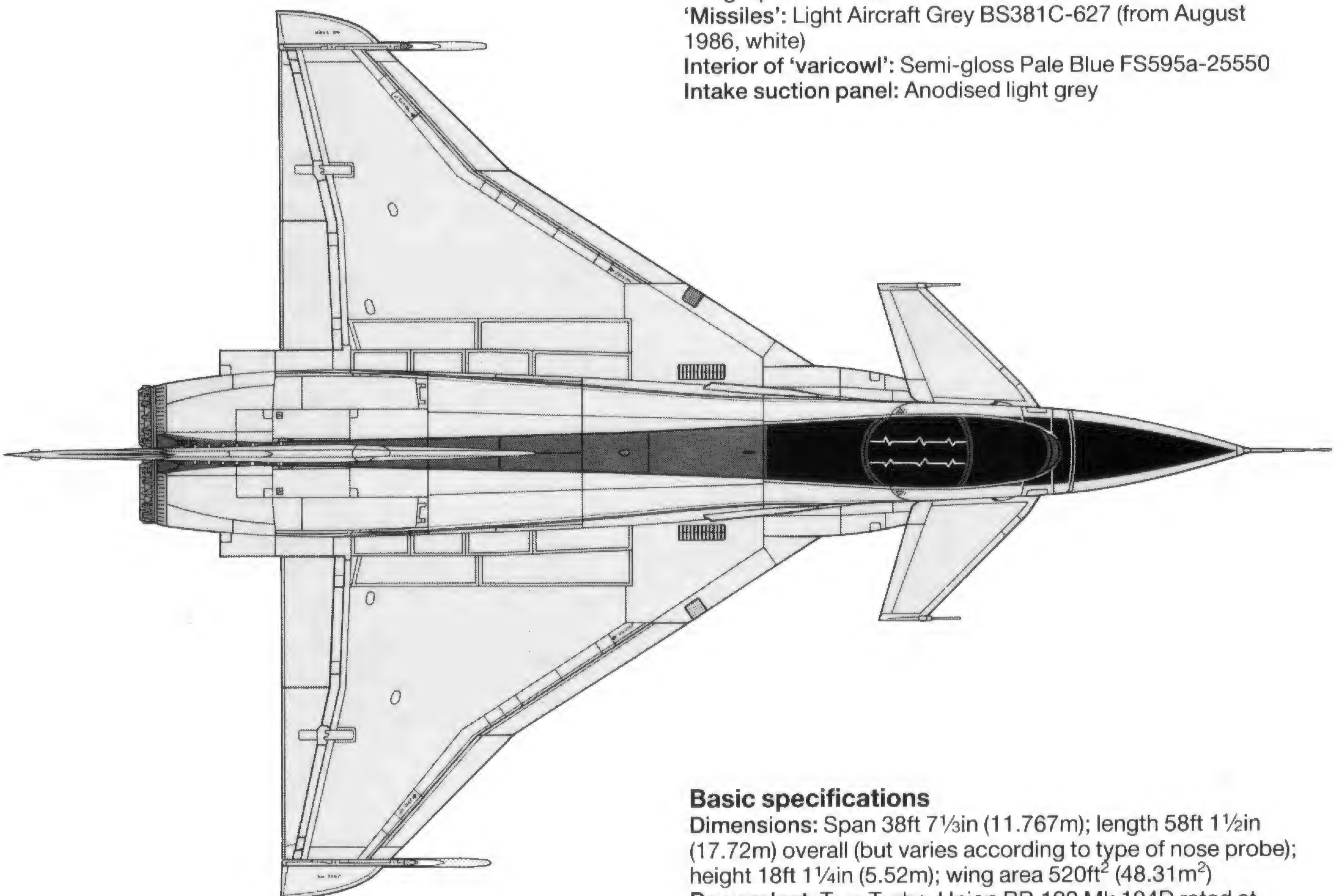
An RB199 Mk 104D powerplant (opposite, bottom) is readied at Warton prior to installation in EAP. The Mk 104D is essentially identical to the engine fitted in the Panavia Tornado, though lacks thrust reversers. *Rolls-Royce*

EAP in close-up (3): the photos on this page show the main undercarriage gear (left and below left) and the nosewheel unit (below right). Legs are extended in two of the pictures with the aircraft undergoing systems testing. *Linewrights*





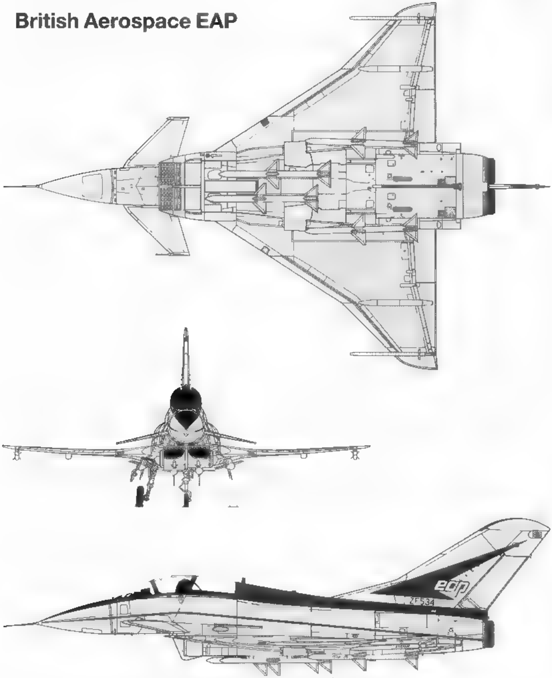
Colour scheme
Airframe: Semi-gloss Pale Blue FS595a-25550
Trim: Semi-gloss Dark Blue FS595a-25056 with semi-gloss Off White FS595a-27880 'EAP' fin logo and upper cheat line
Cockpit anti-glare: Matt Black FS595a-37038
Undercarriage legs and wheel hubs: Light Aircraft Grey BS381C-627
Undercarriage doors: Semi-gloss Pale Blue FS595a-25550
Interiors of wheel bays: Yellowish brown primer finish
Serial number: Black
Wing-tip 'missile' launch rails: White
'Missiles': Light Aircraft Grey BS381C-627 (from August 1986, white)
Interior of 'varicowl': Semi-gloss Pale Blue FS595a-25550
Intake suction panel: Anodised light grey



Basic specifications
Dimensions: Span 38ft 7⅓in (11.767m); length 58ft 1½in (17.72m) overall (but varies according to type of nose probe); height 18ft 1¼in (5.52m); wing area 520ft^2 (48.31m^2)
Powerplant: Two Turbo-Union RB.199 Mk 104D rated at about 18,000lb (8165kg) each
Weights: Empty about 22,050lb (10,000kg); clean gross about 32,000lb (14,510kg)
Performance: Maximum speed at altitude 'in excess of Mach 2'

1:96 scale

British Aerospace EAP



POWERPLANT

A production EFA would have the new EJ.200 engine, to be developed and produced by the Eurojet Engines group formed by companies in the four partner countries – Rolls-Royce, MTU, Fiat and Sener – on the basis of the two-spool Rolls-Royce XG-40. No more advanced fighter engine will exist anywhere, and it should remove any propulsion problems from that hoped-for aircraft. For the EAP the obvious engine was the Turbo-Union RB.199 three-spool augmented turbofan, and it should not be felt that this is in any significant way a second-best choice. Compared with any other existing engine, such as the General Electric F404, it is much shorter and more compact, it has a lower fuel consumption, and in most regimes it has a higher thrust.

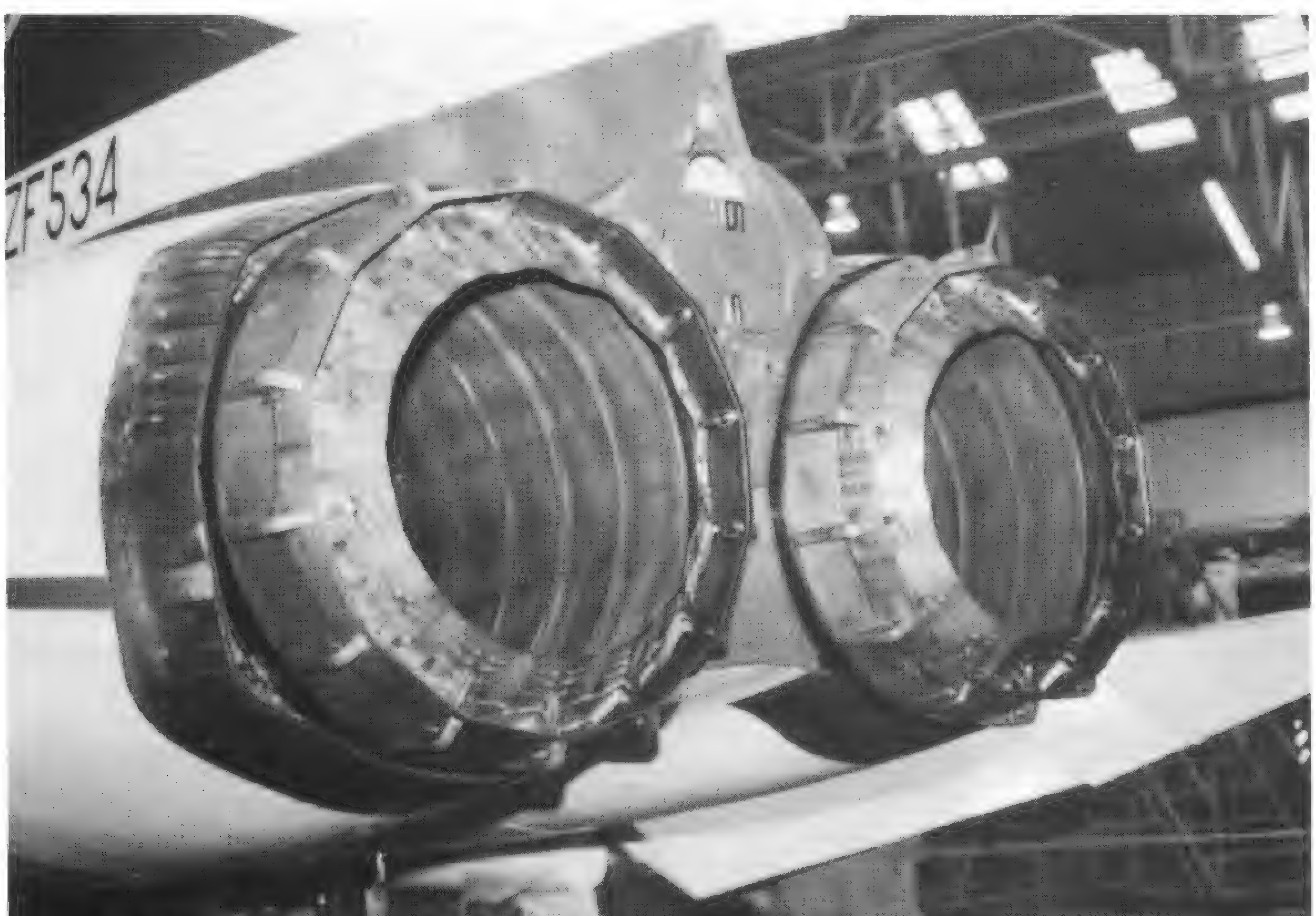
Turbo-Union RB.199 engines during final assembly at Bristol. These particular units are for Tornado installation, witness the thrust reversers at the tail pipes. *Rolls-Royce*

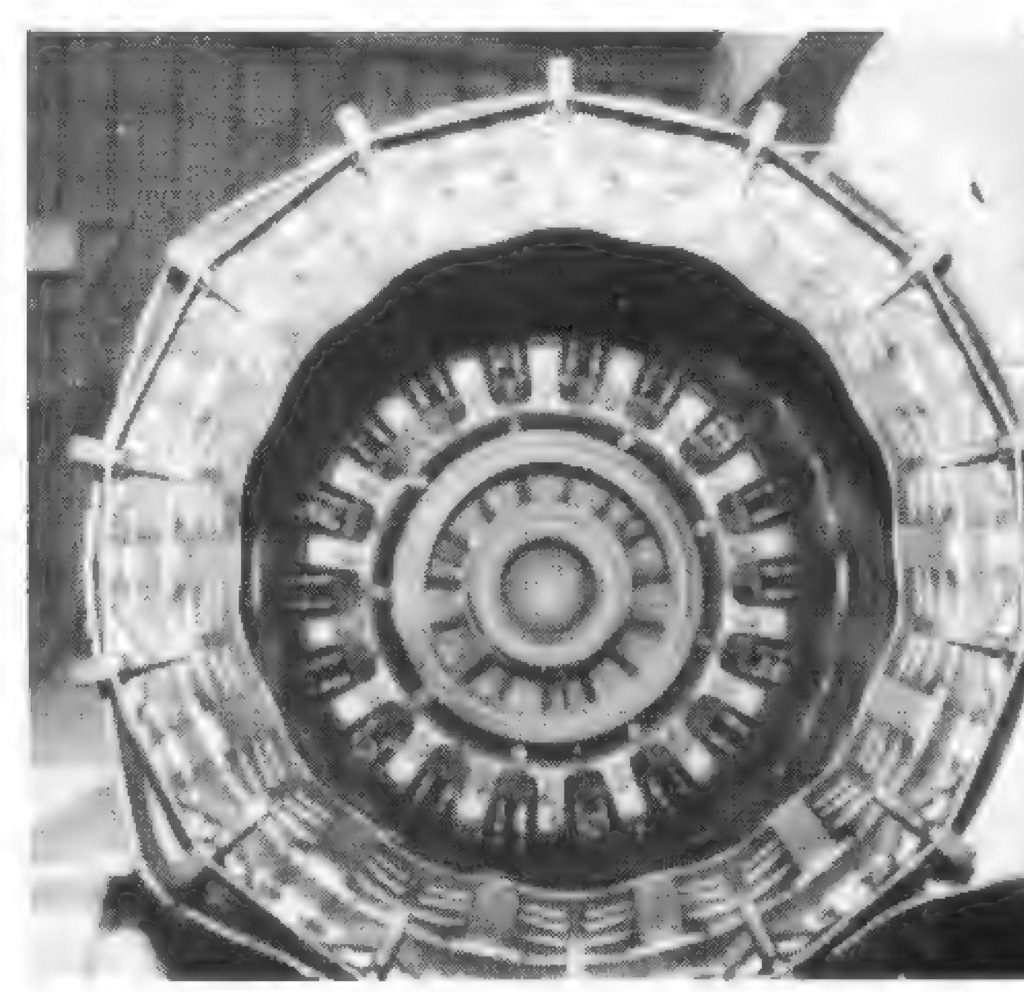
The engines are in fact standard Mk 104s with extended jetpipes, as produced for the RAF's Tornado F.3 interceptor, the only major changes being the removal of the reversers and some simplification and alteration of the accessories. The complete powerplant, only 3607mm (11ft 10in) long and weighing just 1980lb, can be removed straight out to the rear running on overhead rails, the installation being broadly similar to that of the Tornado. There is unobstructed access to the fittings via large doors in the flat underside of the rear fuselage. In all Tornados both engines drive a complicated SPS (secondary power system) with linking cross-shafts and a gas-turbine APU which can drive the accessories without running the main engines and also, via the drive gearboxes, can crank both main engines in sequence for starting. A broadly similar arrangement may be used on EFA, but today's EAP has a simpler Lucas-Rotax SPS with electric starter/generators.

Careful fire protection measures include comprehensive detection and extinguishing systems, and the firewalls between the engines and certain other bay areas are made of SPF/DB titanium. In sharp contrast to most other fighters, especially those from the Soviet Union, the appearance of the EAP is not marred by a single auxiliary cooling inlet anywhere on the outer skin.

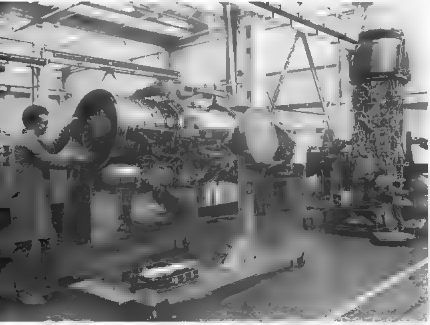
Approximately 10,000lb of fuel is housed in the integral wing tanks and in fourteen tanks in the fuselage, above, between and alongside the engine ducts. The system is pressure-filled from a connector on the left chine of the inlet under the wing-root splitter plate. There is provision for a flight-refuelling probe, but this is not fitted, and in a future EFA this feature would probably be adopted only by aircraft for Britain's RAF. The system is automatically controlled to preserve CG (centre of gravity) position at the optimum location, no attempt being made to use fuel to trim out the pitch changes experienced during transonic acceleration and deceleration (these are trimmed out by varying the lift on the canards). The fuel system is vented via a valve and overboard dump pipe in the top of the fin.

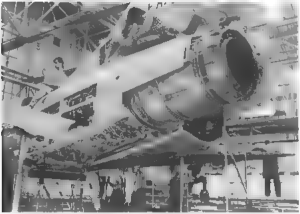
Extremely hot high-pressure air is bled from the engines and piped along inside the tapering fuselage spine to the ECS (environmental control system) aft of the cockpit. Here it is expanded through a high-capacity precooler and an intercooler, and mixed with fresh cold air extracted from a ram inlet between the main inlet splitter plate and the underside of the fuselage. The intercooler exhaust is dumped overboard through a prominent oval aperture immediately above the left wing root. Precooler exhaust is discharged through a corresponding duct on the right.





EAP tail pipes, showing nozzle details (above and left). *Linewrights*





The port RB.199 installed in EAP during the aircraft's assembly (left). The Mk 104 version of the engine powers the F.3 variant of the Tornado ADV. F.2s and the IDS Tornado IGR Mk 1 in RAF usage fly with Mk 103s, which have a tailpipe 14in shorter. Lucas have supplied a digital engine control unit (DECU) for EAP, mounted in the avionics bay; it controls thrust in both the dry and afterburning regimes.

AVIONICS & INSTRUMENTATION

It is in the realm of avionics that today's EAP differs most from a future EFA. As a quasi-civil demonstrator, EAP has no provision for weapons, other than dummies, nor for dedicated combat mission equipment, though of course the nose is structurally a radome. On the other hand it sets entirely new standards in avionics technology and architecture where British aircraft are concerned.

Throughout the 1970s British industry worked with the Royal Aircraft Establishment and Department of Trade and Industry to develop integrated avionics systems based on the MIL-1553B standard for a multiplex digital data bus. This work has culminated in an outstanding system, designed into EAP from the start, which integrates almost every functioning item in the aircraft. The basic avionics systems are for CNI (communications, navigation and IFF), the other two major avionics groups being the USMS (utility services management system) and the FCS (flight control system).

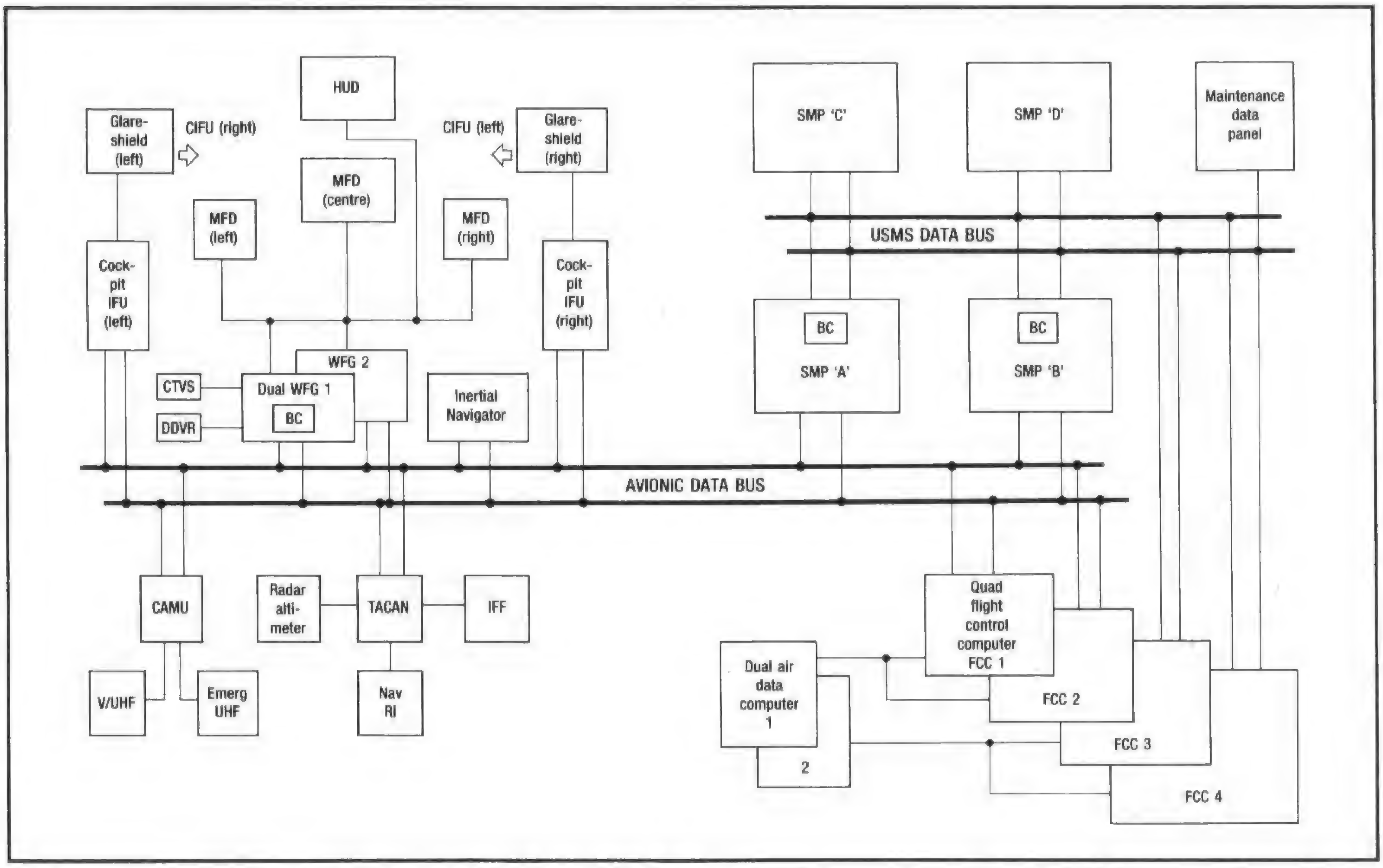
The main avionics bus ties in all the cockpit interfaces and displays with such CNI items as the Ferranti FIN.1070 INS (inertial navigation system), GEC Avionics AD.2780 TACAN, radar altimeter, IFF and, via a Racal RA.800 audio control system, the VHF/UHF and emergency UHF. There is abundant capability to integrate weapon controls at a future date.

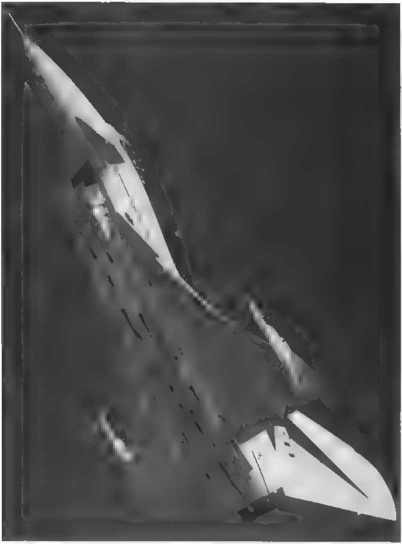
The USMS is one of the main advances in EAP, and nothing like it is yet flying on any other British aircraft. In the block diagram it looks simple, but in fact it links over 600 different kinds of input and output signal from electrically controlled items in every part of the aircraft, plus over 100 power drives. Its special USMS bus links four SMPs (system management processors), each with its own BC (bus controller) and an MDP (maintenance data panel). Two of the SMPs handle aircraft systems and bus control in the forward part of the aircraft, while the other two manage those towards the rear.

Among the functions handled by the USMS are engine control and indication; fuel management and gauging; hydraulic system control, including anti-skid wheel brakes; ECS control, including cockpit temperature monitoring; SPS (secondary power system) control; liquid oxygen control; electric generation and distribution and battery monitoring; pitot head heat; and, if fitted, the EPU (emergency power unit). Such a system reduces weight and cost, improves reliability and resistance to battle damage, facilitates health/usage monitoring and performance/maintenance analysis, and vastly simplifies maintenance, repair and system reconfiguration or modification. The main cockpit interfaces are so-called soft keys around the MFDs (multifunction displays). The same displays automatically give visual warnings of any malfunction, backed up by an increasingly loud female voice in the headset. The pilot can immediately call up the relevant subsystem or line item schematic display in order to obtain more detailed information on the failure, and in almost all cases he can take at least some remedial action during flight to minimise the consequences of the fault. ▶

EAP looks every inch an advanced aircraft, but its attractive lines do not show the feast of new avionics technology that the programme represents. Without doubt it is the most impressive avionics package ever developed in Britain, perhaps in the world.

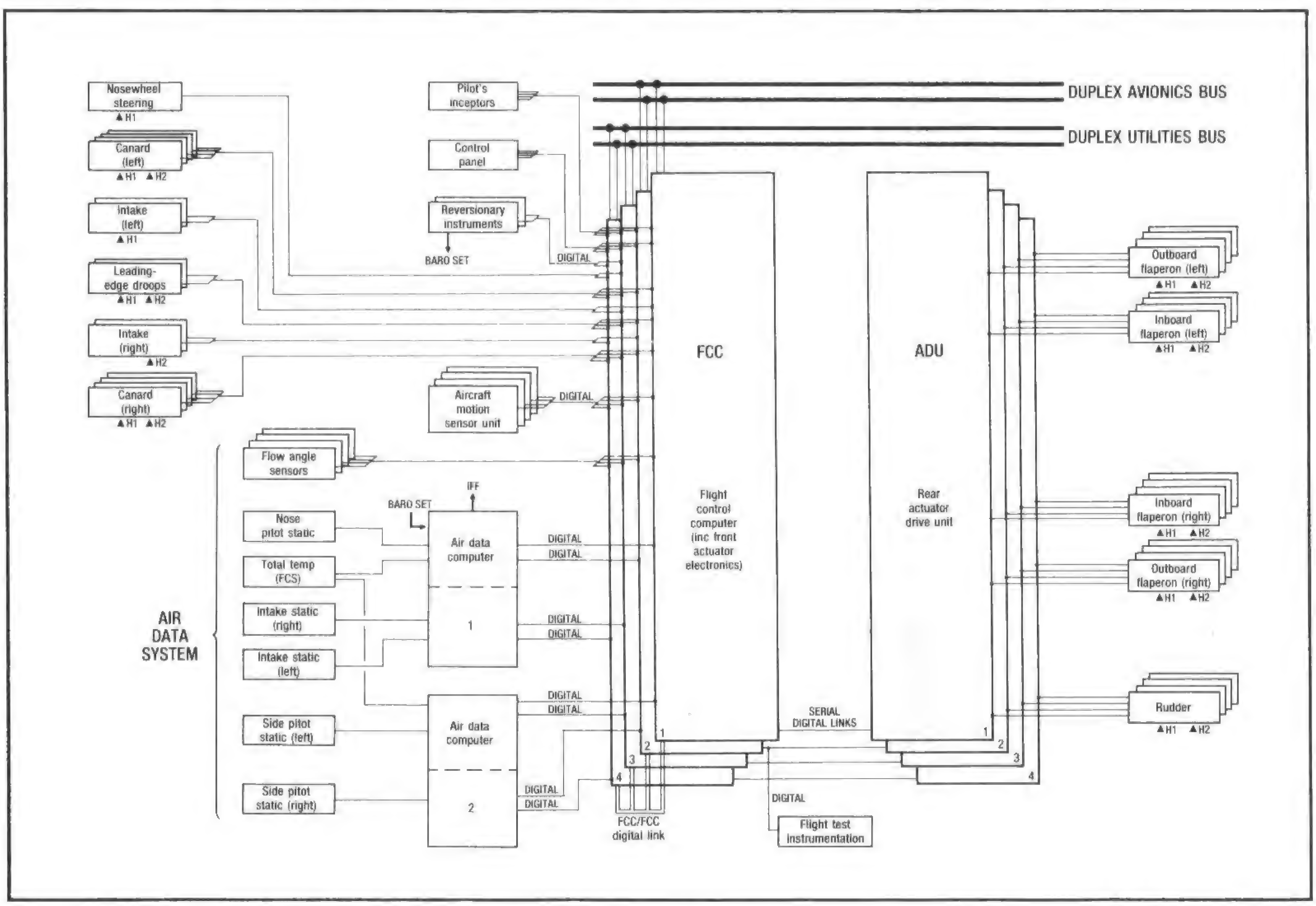
A schematic diagram illustrating EAP's avionics architecture.





BAe test pilot Peter Orme samples the cockpit during a 'strap in' session at Warton (left).

Some idea of the complexity of EAP's flight control system can be gained from this schematic diagram (below).

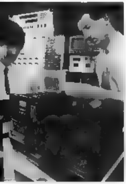


EAP cockpit lighting control system (left), just one aspect of the contribution being made by Smiths Industries. *Smiths Industries*

The two forward and two rear SMPs are all single LRU (line-replaceable unit) boxes with comprehensive self-test features. They use HOL (higher-order language) and dense memories all arranged on standard electronics boards with embedded power switching. All items are fully modular and it is expected that, throughout the lifetime of EAP, many items will be repeatedly updated as the overall technology advances.

A typical 'first' for EAP is that no previous British aircraft has had an integrated control of cockpit lighting. This is a much bigger task than merely turning a switch. The relevant LRU linked to the main bus, contains a computer with inputs from light sensors located around the cockpit. The computer monitors all the sensor outputs and continuously regulates the power supplied to each CRT (cathode-ray tube), LED (light-emitting diode), filament lamp, ELP (electroluminescent panel) and caption in order to achieve optimum illumination and display contrast at all times. The pilot has a day/dusk/night switch giving an extra coarse control, whilst an anti-flash switch enables him to select maximum brightness on all displays ►

The importance of EAP is such as to have driven one leading defence journal to describe it as 'the saviour' of the UK avionics industry (above).



'Carefree' handling is possible only because of the highly advanced flight control computers (FCC) shown above – and there is no back-up in EAP. *GEC Avionics*

Peter Orme again (right), in relaxed mood in the cockpit

in the event of a sudden massive increase in external light level for example on emerging from cloud into brilliant sunshine.

EFA artwork shows a slender nose, but it must house an advanced multimode look-down radar. The latter may be derived from the Hughes APG-65 used in the F/A-18 Hornet, made by Hughes, GEC Avionics and AEG.

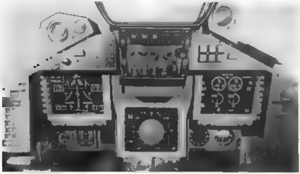
The cockpit is gained via an external ladder, and it is permissible with soft boots to stand on the canard. The canopy hinges to the right and it lies between a one-piece moulded polycarbonate windscreen, which meets full bird-strike requirements and hinges forward for access, and a transparent spine section over the avionics bay where flight-refuelling piping and valves are also installed. The vital seat is the new Martin-Baker 10LX, a 10L zero/zero pattern modified by having a simpler manual separation handle on the left and twin canopy penetrators at the top. The latter enable the seat to go through an intact canopy in emergency, though the canopy naturally incorporates an MDC (miniature detonating cord) to shatter the transparency beforehand. To improve the pilot's *g* tolerance the seat is inclined backwards at 25 degrees.

After carefully studying sidestick controllers, BAe gave the EAP a conventional control column, though of course complete HOTAS (hands-on-throttle-and-stick) philosophy was followed from the outset. HOTAS means that in combat the pilot need never take either hand off the throttles (left hand) and stick (right hand). As the illustrations show, the front panel is dominated by three large full-colour MFDs (multifunction displays). These are part of a major contribution funded by Smiths Industries, other elements of which are the waveform ►

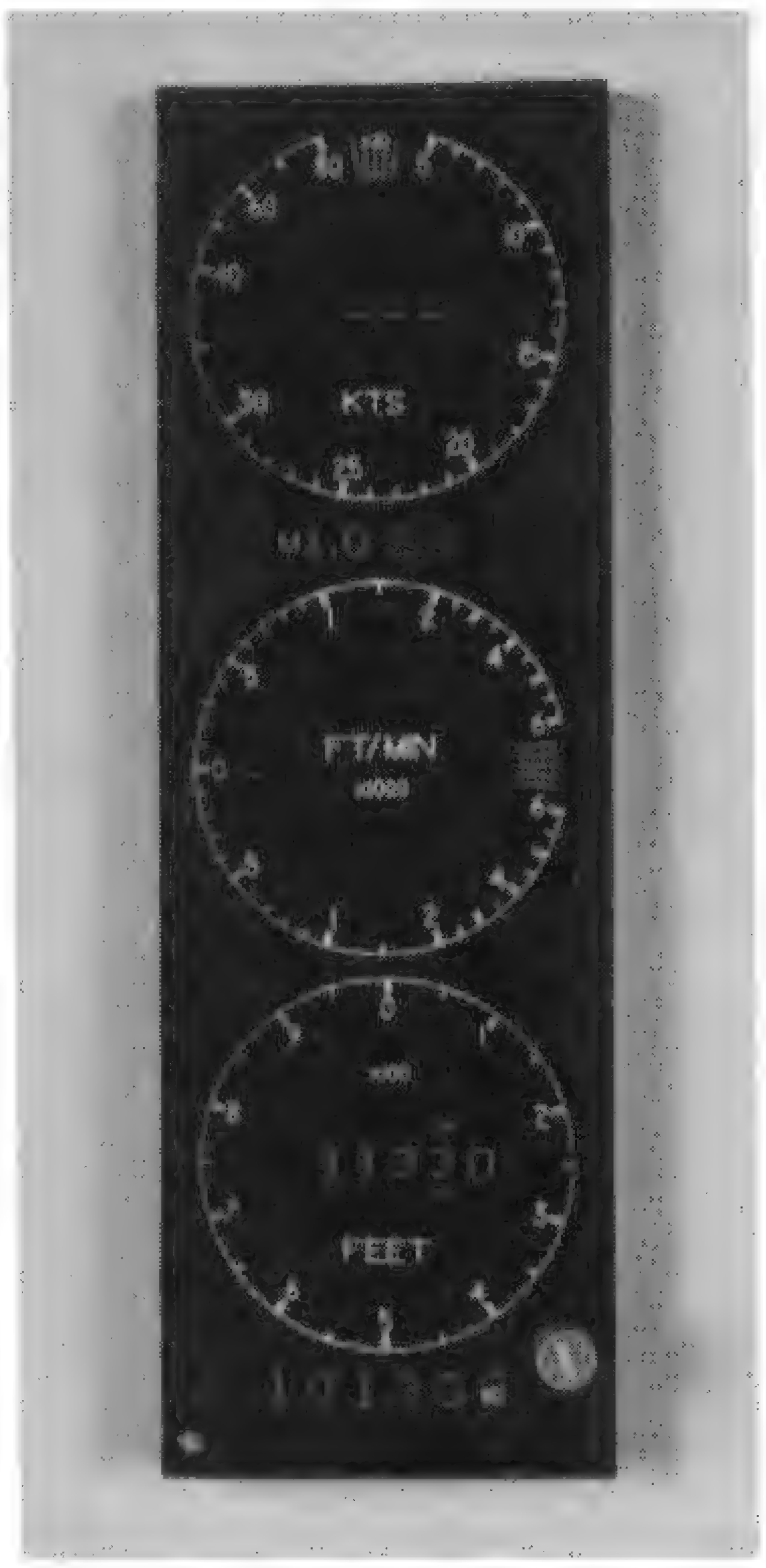
The cockpit (far left) showing a layout quite unlike that of any other British aircraft. The three MFDs are clearly discernible, topped by an enormous, green-tinted holographic HUD.

The Martin-Baker Mk 10LX ejection seat developed specifically for EAP (centre left). The basic 10L is already earmarked for an impressive list of aircraft, including the Saab-Scania Gripen (for which BAe is producing the largely CFRP wing), the IAI Lavi, the Aeritalia/Macchi/Embraer AMX and the Sikorsky/NASA X-Wing helicopter. *Martin-Baker Aircraft Co*

'Feel' has to be built in to the EAP's control stick, since the FBW system offers no conventional resistance for the pilot. Here (left) the sensor assembly (PSSA) for the stick is shown. *GEC Avionics*

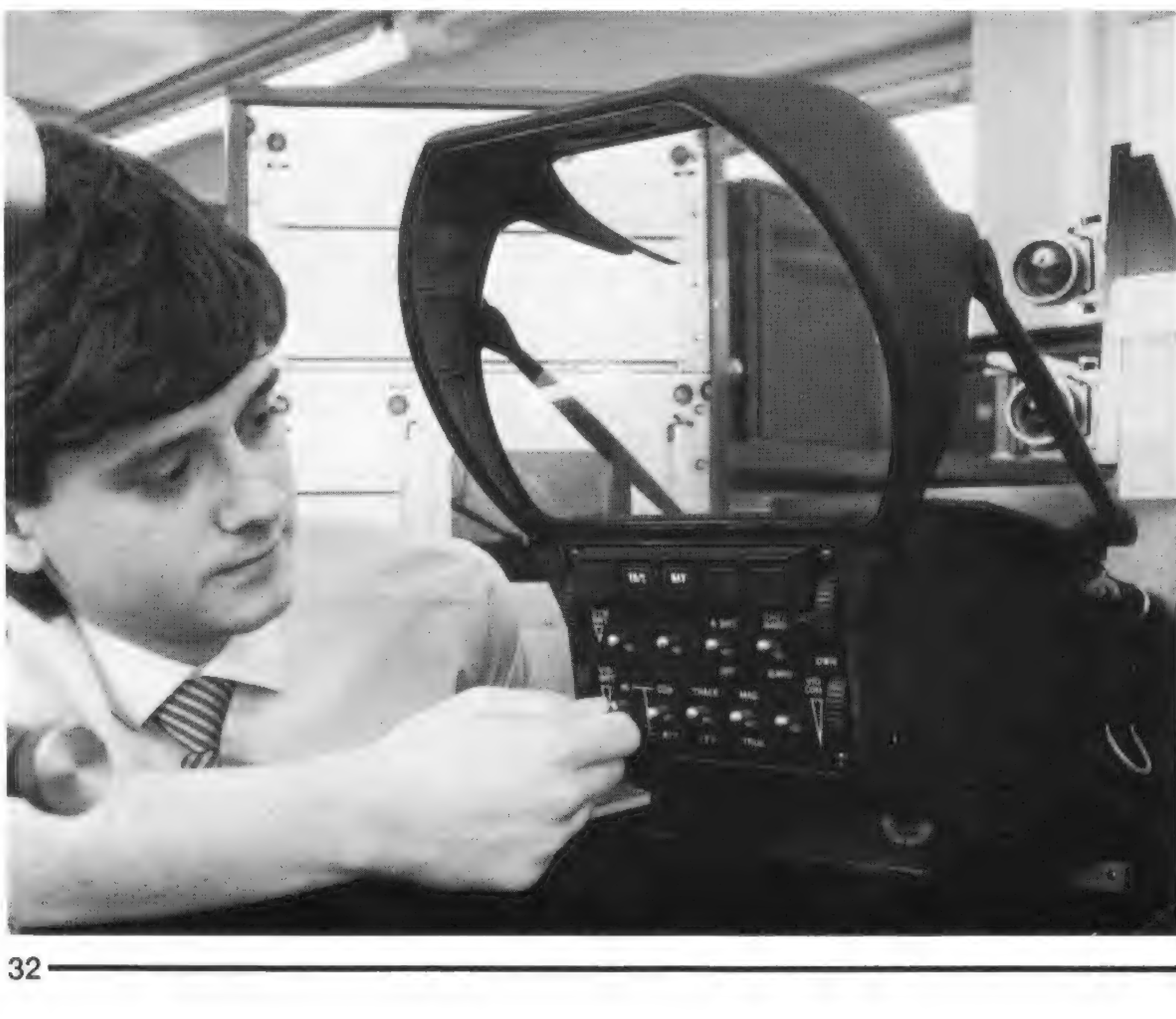


The three MFDs are functioning in this photo (left). Each can operate in three modes, cursive, raster or hybrid, pilot interaction being achieved via two dozen soft keys located around the edges. Smiths Industries produce the MFDs, with an external generator developed by VDO. Lucas have provided all the cockpit electroluminescent panelling and floodlighting. *Smiths Industries*



Despite the 'fail safe' nature of the computerised equipment installed in EAP, no one can afford to take chances, so basic 'get you home' instruments are built into the cockpit. Above left is the reversionary attitude and heading indicator unit, located beneath the right-hand MFD; above right is the standby air data panel, comprising IAS and Mach number (top), vertical speed (centre) and altitude with barometric setting and read-out (bottom) and positioned to the right of the standby navigation instruments. *Smiths Industries*

GEC is the world's biggest supplier of head-up displays – its equipment furnishes the cockpits of the F-16, A-4, A-7 and F-20 amongst many other types – so it is no surprise that the company also provides the futuristic HUD for EAP (below). *GEC Avionics*



generators, the avionics bus executive and control functions, the USMS; the lighting management system, a 'get you home' panel with electronically generated reversionary instruments — airspeed/Mach, VSI (vertical speed indicator) and altimeter, and attitude and heading indicators, a fuel measurement system, glareshield panels, and a radar altimeter.

Dominating the view ahead is the giant holographic HUD (head-up display), which is a GEC Avionics product derived from that in the F-16C and offering the remarkable field of view of 30 degrees in azimuth and 16 degrees vertically. Normally the pilot flies looking through the HUD, but he will also be aware of the three MFDs, whose normal modes are engine data (left), attitude/navigation (centre), and warnings or configurations (right). Nevertheless, each MFD can be reprogrammed by a single 'menu' button to present any of fourteen different formats, giving any information, in any detail, the pilot could possibly want. An alternative 'step' button pages through each format in turn. In an emergency a single button on the stick instantly returns all MFDs to their primary format, as described. Much later EAP may be fitted with combat sensors such as a radar and FLIR (forward-looking infra-red), whose pictures would be displayed on an MFD operating in a 625-line raster (TV-type) format.

Apart from the small reversionary instruments just described, there are hardly any conventional instruments. All the panel and side console area has been carefully allocated to give an overall impression of uncluttered efficiency. The throttles and stick are ergonomically designed, with 'switchology' conforming to the latest practice so that any pilot familiar with, say, an F-15C or F-16C would find little difficulty.

Where EAP is expected to knock all existing fighter-type aircraft for six is in the matter of all-round performance and agility. The Warton designers have no doubt that they have achieved the optimum high-lift, high-thrust, low-drag, lightweight, totally unstable fighter demonstrator of the current generation.

Taxiing out for the first flight

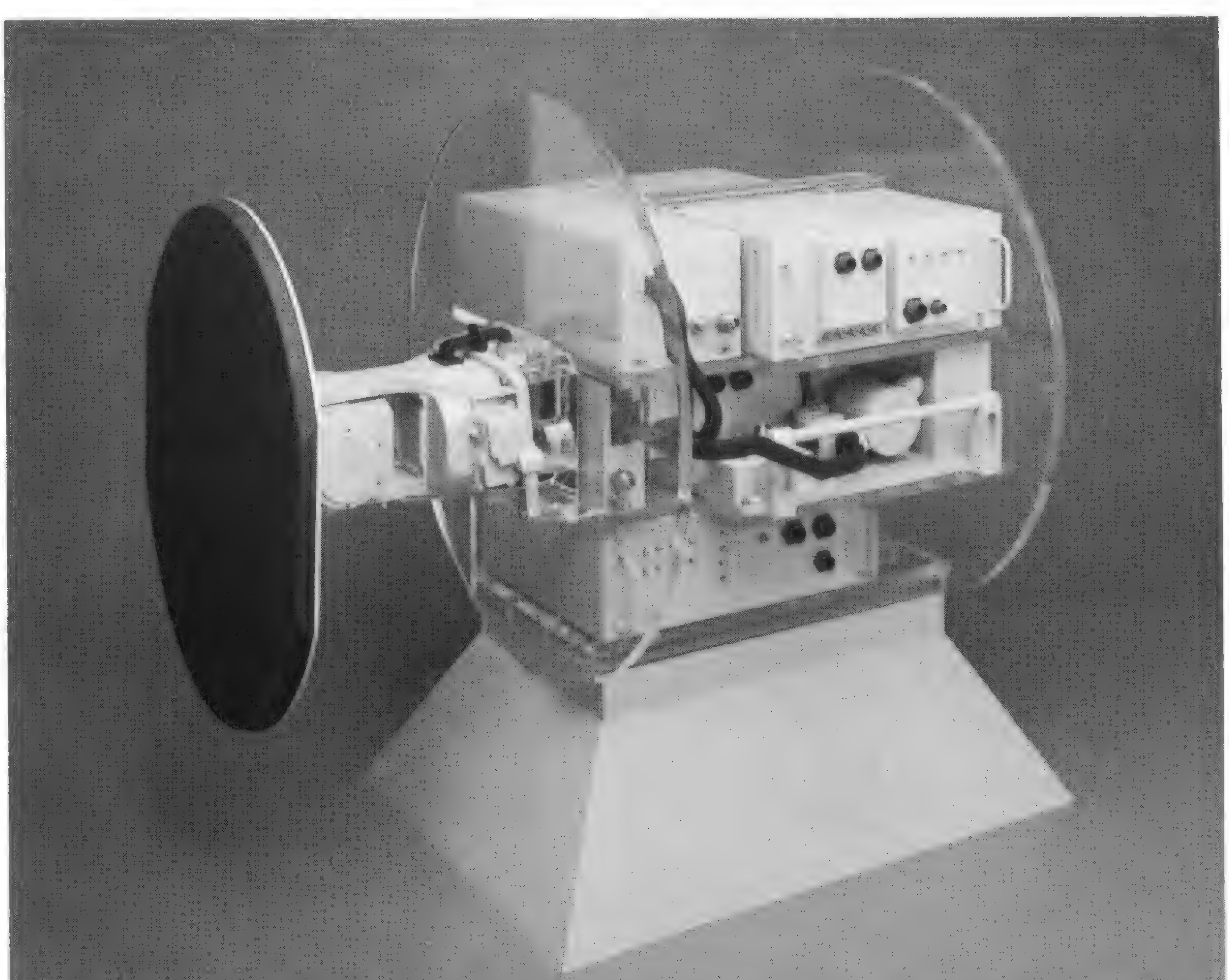
THE FUTURE

Perhaps the only really controversial feature of the EAP is that it has no internal gun, and no provision for one. The British Air Staff, who very strongly influenced the mission requirements of what is at present a purely national aircraft, have convinced themselves no gun will ever be needed. Air-to-air missiles (AAMs), it is argued, will by 1995 be so lethal that target ranges will never become short enough for a gun to be usable. Suffice it to say, no other builder of fighters appears to share this view, and it seems to the author, who long ago flew fighters himself, that a single modern gun, far better than anything in use by today's RAF, would be well worth its installed mass and bulk.

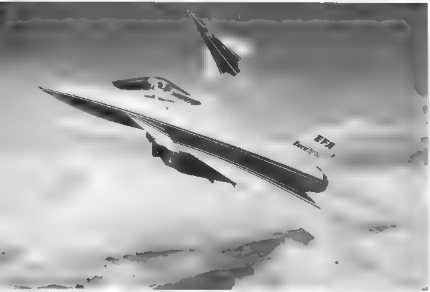
As it is, EAP only makes superficial provision for dummy missiles. The basic kit comprises four BAe Sky Flash or Hughes AIM-120A AMRAAM medium-range AAMs hung under the fuselage and wing roots. BAe describe their carriage as conformal, meaning that the weapons snuggle conformally against the aircraft skin. This is not strictly true. Unlike the similar missiles under the Tornado F.3, the big AAMs stand proud of the skin, with nothing recessed except the upper centreline fins of the under-fuselage missiles. This is instructive, because BAe have conducted exhaustive tunnel testing to refine all missile carriage to achieve the lowest possible drag at both subsonic and supersonic speeds.

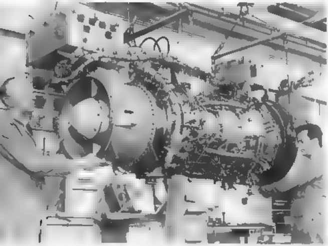
The close-range dogfight AAMs, originally mounted on traditional launch shoes on the wingtips, are now carried on pylons well below the wing and inboard of the important streamwise (Küchemann type) tips. This arrangement gives lower drag, and results in wing lift and drag being unchanged after firing the missile. It has also resulted in almost everyone getting the EAP span incorrect: the true figure is not 36ft 7.8in but 38ft 7.4in (11.77m), greater than that for any of the other new unstable canard fighters now being developed, and partly responsible for the EAP's large wing area of 520ft^2. No matter whether the definitive EFA is lighter or heavier than EAP, this big wing will always be a vital asset in short field-length and in almost every aspect of flight performance and agility. EFA, incidentally, features electronics wing-tip pods.

Without a gun there is a probability that four medium-range BVR missiles and two short-range missiles – Sidewinders, ASRAAMs or similar – will not be sufficient for the 1990s. A future EFA will very likely have provision for upwards of eight missiles in all, at least two probably being designed to home on enemy fighter radars or other airborne emissions. Of course, an EFA would also have an extremely advanced and comprehensive ESM (electronic surveillance measures) installation, far more capable than today's radar warning receivers. It would detect, analyse, identify and locate the exact position of every hostile emitter. Where necessary, it would automatically prepare a missile to eliminate the threat by homing on to it passively. Such a missile would be of the 'fire and forget' type, like AIM-120A. The moment it has left the launcher, the fighter can turn away and seek another target, staying well out of range of the first. ▶



Project definition for EFA is proceeding apace as these words are written, although the question of a radar system has yet to be resolved. GEC and AEG are backing the Hughes-developed APG-65 system as installed in the F-18 Hornet, but Ferranti, FIAR of Italy and INISEL of Spain are proposing ECR 90, an engineering model of which is illustrated at left. A true multi-mode system, ECR 90 will operate in X-band and would draw on design experience from, in particular, the Blue Vixen radar now in production for the Sea Harrier FRS.2. *Ferranti Defence Systems*





One of the most recent impressions of EFA (above) showing its single fin, straight wing leading edge and wing-tip [illegible]. Hard facts are difficult to come by at this early stage, but wing area has been given as 50m², sweepback as 53 degrees, basic empty weight as 9,750kg and engine thrust as 90kN (about 20,000lb).

The core of the XG-40 military engine demonstrator (left), which is a completely new turbofan from Rolls-Royce and could form the basis for the EFA powerplant. *Rolls-Royce*

The EFA full-scale mock-up, displayed at the 1986 Farnborough Air Show. *Ferranti Defence Systems*

A giant-winged fighter is very far from being the ideal low-level attack and reconnaissance aircraft, but an EFA would of necessity be so expensive and well-equipped that it would have to have some capability in these other roles. Already BAe is talking about 'low-drag carriage of air-to-ground stores' on today's EAP, though it is not clear just how this would be achieved. Certainly, at a considerable penalty in speed and agility, EAP or a derived EFA could carry ten tons of external weapons and still have a take-off run quite good by comparison with today's fighters.

There remains the vexed question of stealth. The author unkindly suggested to a designer from elsewhere in BAe that 'Warton have now heard of stealth, and felt they had to include the word in the brochures'. The reply, perhaps rather partisan, was 'That's precisely how it is'. This is a little unfair to Warton, who have been talking with Ministry of Defence establishments and industry for some time about how this vital new technology should best be incorporated. In the author's view, stealth qualities cannot be added to an existing aircraft: all that can be done is to add RAM (radar-absorbent material) coatings and apply minor cosmetic treatment to a few highly reflective areas. EFA will have to have more completely screened engine inlets and ducts, the elimination of the large flattish areas at 90 degrees to each other on the sides of the duct under the ogival splitter plate (which itself may be enlarged), and possibly a more blended wing/body junction. As for the horrendous afterburners with plain holes, these may be permissible on take-off and possibly when engaging in close air combat, but in the longer term this kind of propulsion must surely be rethought.

At the time of writing it is expected that the Eurojet EJ.200 engine might go into production in about 1993. The announced requirements for an EFA are 250 aircraft each for the United Kingdom and West Germany, 150 for Italy, and 100 for Spain. On this basis, BAe might have a 33 per cent share in a future Panavia-style company, making the nose and forward fuselage; MBB would also have 33 per cent, making the centre fuselage; CASA of Spain would have 13 per cent, making the rear fuselage and fin; and Aeritalia would have 21 per cent, building the wings. Various minor parts might be allocated to partners who have yet to join, of which several have expressed an interest. Ironically, one of these is France, who have been told 'Fine, but don't alter our drawings!'.

British Aerospace EAP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The Experimental Aircraft Programme has resulted in the production of an outstanding combat aircraft demonstrator, the most technically advanced flying machine ever built in Great Britain. EAP is the tangible expression of years of research and development carried out by one of the world's most talented design teams, but it is much more than this: it is also the result of an unprecedented collaborative effort, involving British Aerospace, the UK Ministry of Defence, Aeritalia and very many individual partner companies in the United Kingdom, Italy and West Germany.

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Text
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Artwork
Mike Keep

Book Design and Production
Roger Chesneau

Special thanks to
British Aerospace • Rolls-Royce
Smiths Industries • Lucas Aerospace
Ferranti Defence Systems • GEC Avionics
Dowty Group • Martin-Baker Aircraft Co

ISBN 0-946958-22-X

9 780946 958221

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